A MANUAL

OF

THE GEOLOGY OF INDIA.

CHIEFLY COMPILED FROM THE OBSERVATIONS OF THE GEOLOGICAL SURVEY,

BY

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PART I: PENINSULAR AREA.

PREFACE.

THE want of a general account of Indian Geology has been felt for some years. The regular Geological Survey of India may be considered to have commenced in 1851; and but few of those who took part in the work during the earlier years now remain in the Service. It is desirable, before all the older Members of the Survey pass away, that some record of the early observations, many of which are unpublished, should be rescued from oblivion, for the benefit of future explorers. The published Memoirs and Records of the Survey, moreover, have now become too numerous and bulky for general use; and it is difficult for any one, without much study, to gather the more important observations on the geology of the country from amidst the mass of local details. Many papers on Indian Geology are also scattered through various Indian and European periodicals. As a guide to all who have occasion to acquire a knowledge of Indian Geology, or who desire information from a love of the science, some compendium of the observations hitherto collected has become absolutely necessary; and the present Manual has been drawn up, by direction of the Government of India, to supply the deficiency.

It was originally desired by the Government that this work should be prepared by the late Dr. Oldham, or that the compilation should have the advantage of his supervision. As Dr. Oldham was the first Superintendent of the Survey, and

remained at the head of the Department from its commencement in 1851 to 1876, he would, unquestionably, have been admirably qualified to carry out the work; and it was his own desire to do so, as the completion of his labours in India. Failing health, however, and the pressure of other duties, prevented him from even commencing the task; and when, at length, he was unable any longer to remain in the country, the duty of preparing a Summary of Indian Geology was left to his successor. At this time, the only preparation that had been made for the work was the partial compilation of a general Geological Map of the Peninsula.

The double authorship was not entirely a matter of choice; although undertaken, and carried out, most willingly by both the writers. Both have been engaged in the work of the Survey almost from the commencement; and as each has, in the course of his service, examined very large areas of the country, the combination secures the description and discussion, from personal knowledge, of a much larger portion of India. At the same time, the advantages of wider experience and thought may not be found an adequate compensation for want of uniformity and occasional discrepancies—the natural results of divided authorship. To secure, so far as possible, the responsibility of each author for the facts and opinions stated, the initials of each are affixed in the Table of Contents to the chapters contributed by him. Every such chapter has been read and revised by the other writer; but the alterations have in no case been of more than trivial importance; so that each chapter may be practically taken as an individual contribution. The number of subjects is so large, and the connexion between them, in many cases, so slight, that the lack of uniformity will not, it is hoped, seriously detract from the usefulness of the Manual.

In addition to the subjects discussed in the present work, it was, at first, proposed to add an account of the Economical Geology, and to treat in a special chapter of the known Mineral Resources of India. But the length to which the Manual has already extended, has rendered it advisable to

postpone this very important subject, and to reserve it for a separate volume.

Although many of the details in the work now issued have not previously been published, and although the discussion of the observations involves several new deductions and suggestions, the book is, in the main, a compilation; and it is quite possible that, especially in treating of areas and formations of which the authors have no personal knowledge, full justice has not always been done to the views of original observers. It has, in several instances, been thought more important to point out possible causes of error, than to endorse opinions which, although very possibly correct, are not sufficiently supported by published data to be accepted as conclusive. In all such cases full references to previous publications have been furnished; and an examination of the details given in the latter will, it is hoped, serve to correct any errors of interpretation on the part of the authors of the present work.

The numerous and large areas left blank in the annexed Map shew, at once, how far the present publication falls short of completeness, and how imperfectly the promise implied in the title is fulfilled. A note upon the Map further explains, that large portions of it have been coloured from very imperfect information, from sketch surveys or rapid traverses, affording no sufficient opportunity for a proper study of the formations. It had, however, become imperative, as a duty to the public, for reasons already mentioned, to bring together a summary of the work accomplished since the commencement of the Survey; and it was equally essential for the Survey itself, that some general record of the results obtained up to date should be compiled. These objects could only be attained by attempting a general Map and Review of the Geology of India; but the reader must not forget that the present attempt is more of the nature of a progress report than of a finished work.

The Map, it is feared, will be found defective in several other respects. Under the circumstances, it was impossible

to prepare a special reduction of the topography; and, amongst the Maps of India available in the Surveyor General's Office, there was, practically, no choice but to accept that on the scale of 64 miles to the inch, then well advanced towards completion, as a basis for the geological details. The scale is inconveniently small for all parts of the country that have been geologically mapped in any detail, and the mountain ranges have not been inserted; so that many features discussed in the text are not indicated. But the most serious drawback is in the names of places. Many towns of importance are omitted, owing to the small scale; and other names of interest, for purposes of geological description, such as those of fossil-localities, or of villages near important sections, are wanting. Nor is this all. The spelling of Oriental names is a well-known cause of perplexity; and the confusion has been increased by the unfortunate circumstance that, while one system has been adopted by the Great Trigonometrical Survey, and employed in all the maps, including those of the detailed Topographical Surveys, issued by the Department, an entirely distinct system has been employed by the Revenue Survey, by whom the maps of all the best known parts of the country have been prepared. Under the first system, each letter in the Indian language is represented by a corresponding letter in the Roman character; diacritical marks and accents being employed to distinguish such consonants or vowels in the latter as are required to represent two or more sounds, and the Italian or German sounds of the vowels being used, instead of the English. Under the second system, an attempt is made to represent the original sound by English spelling; double vowels being largely used, but no diacritical marks. The imperfection of the latter plan is manifest; because, in the first place, the sounds, of the vowels especially, in English, are variable, and incapable, in many cases, of representing those of Oriental languages; and secondly, the representation of the true names by supposed equivalents is arbitrary, depending chiefly on the ear, often very imperfectly trained, of the

transcriber. When maps of large areas, as in the present case, are compiled, the mixture of names, spelt according to two different systems, is inevitable. The attempt at a general revision of the nomenclature, however desirable, would have involved serious delay.

Of late, the Government has adopted a compromise in the question of spelling, and lists of the principal places in each province have been issued; the familiar and well-known names being spelt in the manner that has become customary by usage, whilst transliteration is employed in all other cases, with the exception that no diacritical marks are used for consonants. This system is obligatory for all official publications; and it has, consequently, been adopted in the present work. In some cases, however, the lists for particular provinces have not been published in time to be available; and in the following pages it is not unfrequently necessary to mention places not contained in the lists, and the proper vernacular pronunciation of which is unknown to the writers. In such cases, an attempt has been made to spell the name according to the recognised system; but it is only fair to warn the reader that no dependence can be placed on many names of places, especially upon those in the south of India, when taken from old maps.

In the preparation of the Map, a large share has been taken by various Officers of the Geological Survey, all of whom have contributed. The colouring and printing have been carried out at the Surveyor General's Office, under the superintendence of Captain Riddell, R.E., to whom the authors beg to express their obligations for the labour he has given to the work, and for the assistance he has afforded to them personally.

In the plates of fossil plants and animals at the end of the work some of the most common and characteristic forms of organic remains found in India are represented. The plants have been selected and arranged by Dr. Feistmantel, and the tertiary Mammalia by Mr. Lydekker. All the plates are lithographed by Mr. Schaumburg, whose work

will answer for itself. The majority of the figures are from original drawings, or from the "Palæontologia Indica;" the remainder are copied from other works; but these copies have, in many cases, been compared with specimens.

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POST-TERTIARY AND RECENT FORMATIONS—*continued.*—(W. T. B.)

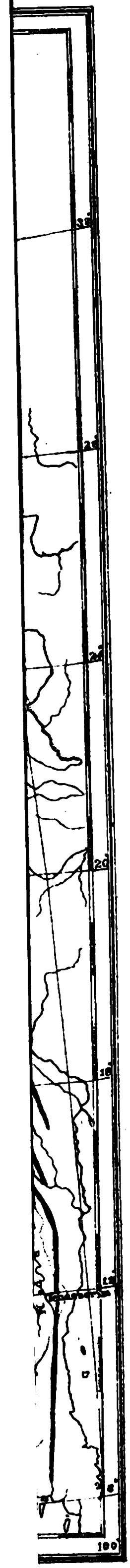
INTRODUCTION.

Nature of present work.—The present, although by no means the first general description of the Geology of India, differs from most previous works on the subject in the extent of the area described, and from all in the amount of information in the hands of the writers. The greater number of the papers hitherto published on the Geology of the British possessions in India and the neighbouring countries have dealt only with portions of the territory; and, since the establishment of a Geological Survey by the Government of India, no opportunity has hitherto been afforded of bringing much scattered information, procured by the Officers of the Survey, but, on account of incompleteness, or for other reasons, hitherto unpublished, into connexion with the published data distributed throughout the Memoirs and Records of the Survey, and the Journals of various Scientific Societies. The urgent need for a general exposition of the present state of Indian Geology has led to the present attempt to combine the observations of all Members of the Geological Survey, past and present, with the information collected by other Geologists, and to give a general view of the existing state of knowledge on the subject.

Limits.—The limits of the country described in the present work coincide in general with those of the territory under British rule or protection: a few notes will occasionally be added on the geological features of countries beyond the boundary, wherever information is available; but this is rarely the case. There is, in general, far more reason for us to deplore the ignorance still existing of tracts in the British dominions, than to congratulate ourselves on our acquaintance with foreign territory beyond the limits of the "red line."

Physical geography of India.—Before proceeding to any geological details, it may not be out of place to glance briefly at the physical features of the region under consideration. With the general outline of the British possessions in India and Burma all are acquainted. The great triangular promontory, with the island of Ceylon south-east of its extremity, to the west of the Bay of Bengal, and the long narrow belt of country along the shore of Burma, with a broader expanse in the Irawadi valley to the southward, and the long narrow plain of the Brahmaputra to the northward, east of the Bay; the broad and high mountain chain of the Himalayas, with the loftiest peaks in the world dotted along its snowy range, stretching in a vast convex curve from west to east along the northern boundary, and forming the barrier between the tropical plains of India and the cold and barren plateaus of Tibet: all these are familiar to every one. But there are a few other peculiarities of the region intimately connected with its geological structure, and deserving of a brief notice; and as the nomenclature of the Indian mountain ranges is by no means definitely settled, it is necessary to explain terms which must frequently be used in the ensuing pages.

Sub-division into Peninsular and Extra-Peninsular areas.—The first of the peculiarities to be noticed is the great alluvial low-level plain of Northern India, watered by the Ganges and Indus and their tributaries; and hence known as the Indo-Gangetic plain. This is an immense expanse of flat country stretching from sea to sea, entirely composed of alluvial deposits of very late geological age, and dividing the hilly ground of the Peninsula from the various mountain and hill ranges of Sind, the Punjab, the Himalayas, Assam, and Burma. It will presently be shewn that this sub-division is not merely geographical, but that a trenchant distinction exists between the rocks of the Indian Peninsula and those of the *Extra-Peninsular area*, as the territories divided from the *Peninsular area* by the Indo-Gangetic plain may be termed collectively. The geological history of these regions is widely different; and even in the characters of the surface there is a marked contrast, due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to the great effects produced by disturbance in late geological times throughout the Extra-Peninsular region—an effect culminating in the elevation of the great Himalayan chain;—whilst in the Peninsula there appears to have been singularly little contortion or alteration of the strata after a very early period. The Vindhyans of Bundelkhand and Central India are certainly not newer than lower palæozoic; yet they are nearly horizontal throughout the greater part of their area; and they are far less tilted and folded than the pliocene Siwaliks along the base of the Himalayas, and of the Punjab and Sind mountains, on the opposite side of the Indo-Gangetic plain.

The first step towards a comprehension of Indian geology is this sub-division of the country into three distinct regions—Peninsular India, the Extra-Peninsular area, and the great Indo-Gangetic alluvial plain separating the two. The plain requires no further description at present; its peculiar features, many of them of singular geological interest, will be found described in the chapters relating to post-tertiary and recent formations. The physical geography of the other regions is less simple. The Peninsula is the most important portion of the British territories in Southern Asia; it comprises the greater part of India proper, and its geology has received much more attention than has that of the neighbouring countries; consequently it requires to be first noticed.

Rivers of Peninsula.—Some of the main features of India and the neighbouring countries are represented in the accompanying sketch map, on which only the principal rivers and the mountain ranges are marked. The rivers of the Peninsula are seen at a glance to comprise two well-marked groups, irrespective of the streams flowing to the Ganges: these groups are—first, the rivers running to the westward, and terminating in the Arabian Sea, the Narbada (Nerbudda), and Tapti (Taptee) being alone of sufficient importance to be noted; secondly, the rivers running to the Bay of Bengal, the principal of which are the Mahánadi (Mahanuddy), Godávari (Godavery or Godavri), Krishna (Kistna), and Cauvery (Cavery or Kaveri). It should further be observed that the only large streams running westward drain the northern portion of the Peninsula, and that, except in a narrow strip of country close to the western or Malabar coast, all the drainage south of the Tapti valley, even from the summits of the hills within sight of the western sea, runs eastward to the Bay of Bengal.

Mountain ranges of Peninsula.—The nomenclature of Indian mountain ranges is still a difficulty, it being a rare exception that any definite term is applied to a mountain chain, throughout its extent, by the people of the country. In many parts of India, peaks and passes

have names, but the ranges have none; and even if names exist, their application is not unfrequently vague. Thus the ancient name of "Vindhya," applied to the hills separating Hindustan proper or the Gangetic country from the Deccan (Dakhin or south) has now, by common consent, been restricted to the hills north of the Narbada; but it appears almost certain that the term originally applied also to the ranges now known as Sátpura, south of the river; and it is very probable that the latter hills were more especially indicated by the term "Vindhya" than the former. The term "Sátpura," again, was of very indefinite application, and probably included other ranges, besides that to which it is now restricted. The names here applied are those employed by the latest writers on Indian geography; but some of them are by no means generally adopted on maps.

The most important mountain ranges of the Peninsula are the *Sahyádri,* or Western Ghâts, running along the western coast, from the Tapti river to Cape Comorin, at the southern extremity of the Peninsula; the *Sátpura,* running east and west, on the south side of the Narbada valley, and dividing it from the drainage areas of the Tapti to the westward, and the Godávari to the eastward; and the *Arvali* (Aravalli or Aravally), striking nearly south-west to north-east, in Rájputána. The so-called *Vindhyan* range, north of the Narbada, and the eastern continuation of the same north of the Son valley, known as the Kymor range, are merely the southern scarps of the Vindhyan plateau comprising Indore, Bhopal, Bundelkhand, &c. The plateaus of Hazáribágh and Chutia Nágpúr (Chota Nagpore) in South-Western Bengal appear to form a continuation to the eastward of the Sátpura range; but there is no real connexion between these elevations and the Sátpura chain; they are formed of different rocks, and there is no similarity in the geological history of the two areas, so far as it is known. In many maps a range of mountains is shewn along the eastern coast of the Peninsula, and called the Eastern Ghâts. This chain, as a whole, has no existence, but is composed, to the southward, of the eastern scarp of the Mysore plateau, and to the northward of the south-eastern scarp of the Bastar-Jaipur plateau, north-west of Vizagapatam, and of several short isolated ridges of metamorphic rocks, separated from each other by broad plains, and having in reality but little connexion with each other. There are also several minor ranges, such as the Rájmahál hills in Western Bengal, the Indhyádri between the Tapti and Godávari, the Nallamalé (Nullamullay) near Kadapah, north-west of Madras, and the little metamorphic plateaus, such as the Shivarais (Shevroys), Pachamalé, Kolamalé, &c., scattered over the low country of the Carnatic, south-west of Madras.

The peculiarity of all the main dividing ranges of India is, that they are merely plateaus, or portions of plateaus, that have escaped denudation. There is not throughout the length and breadth of the Peninsula, with the possible exception of the Arvali, a single great range of mountains that coincides with a definite axis of elevation; not one, with the exception quoted, is along an anticlinal or synclinal ridge. Peninsular India is, in fact, a table-land, worn away by subaërial denudation, and perhaps to a minor extent, on its margins, by the sea; and the mountain chains are merely the dividing lines left undenuded between different drainage areas. The Sahyádri range, the most important of all, consists to the northward of horizontal, or nearly horizontal strata, of basalt and similar rocks, cut into a steep scarp on the western side by denudation, and similarly eroded, though less abruptly, to the eastward. The highest summits, such as Mahábleshwar (4,540 feet), are perfectly flat-topped, and are clearly undenuded remnants of a great elevated plain. South of about 16° north latitude, the horizontal igneous rocks disappear, and the range is composed of ancient metamorphic strata; and here there is in some places a distinct connexion between the strike of the foliation and the direction of the hills; but still the connexion is only local; and the dividing range consists either of the western scarp of the Mysore plateau, or of isolated hill groups, owing their form apparently to denudation. Where the rocks are so ancient as those are that form all the southern portion of the Sahyádri, it is almost impossible to say how far the original direction of the rang is due to axes of disturbance; but the fact that all the principal elevations, such as the Nilgiris (Neilgherries), Palnés (Pulneys), &c., some peaks on which rise to over 8,000 feet, are plateaus and not ridges, tends to shew that denudation has played the principal share in determining their contour.

The southern portion of the Sahyádri range is entirely separated from the remainder by a broad gap, through which the railway from Madras to Beypúr passes west of Coimbatúr. The Anamalé, Palné, (Pulney), and Travancore hills south of this gap, and the Shivarai (Shevroy) and many other hill groups scattered over the Carnatic, may be remnants of a table-land once united to the Mysore plateau, but separated from it and from each other by ancient marine denudation. Except the peculiar form of the hills, there is but little in favour of this view; but, on the other hand, there is nothing to indicate that the hill groups of the Carnatic and Travancore are original elevations.

The whole of the Western Sátpuras, from their western termination in the Rájpipla hills to Asirgarh, consist of basaltic traps, like the Sahyádri, the bedding being, it is true, not horizontal; but the dips are low and

irregular, and have no marked connexion with the direction of the range. The Central Sátpuras, comprising the Pachmarhi or Mahádeva hills, from the gap in the range at Asirgarh to near Narsingpur, are composed chiefly of horizontal, or nearly horizontal, traps, but partly of sandstones and of metamorphic rocks; and there is here again, as in the Southern Sahyádri, some connexion between the strike of the foliation in the latter and the direction of the ranges. The highest peaks, however—those of Pachmarhi (4,380 feet)—are of horizontal mesozoic sandstones. Farther east still the Sátpuras consist entirely of horizontal traps, terminating in the plateau of Amarkantak, east of Mandla. East of this plateau, there is, north of Beláspur, a broad expanse of undulating ground at a lower level; and farther to the eastward, again, the metamorphic plateau of Chutia Nágpúr rises, capped in places by masses of horizontal trap and laterite. These formations were once apparently continuous across the low ground near Beláspur with the same strata on an equal elevation at Amarkantak. Similar outliers occur on the Bundelkhand plateau, north of the Narbada; all tending to the same conclusion—that the low valleys of Central India are merely denudation hollows, cut by rain and rivers out of the original plateau of the Peninsula. The chief exceptions to this law—the instances in which the strike and dip of the rocks appear to have produced important effects on the contour of the country—are to be found amongst the metamorphic and transition formations.

It is true that some small ridges are formed of azoic and mesozoic sandstones, in places where the beds of these systems have been disturbed; but the only important lines of disturbance in either appear to be due to older axes of metamorphic foliation; and it is a rare case to find that the strike of the sandstones appears to have much effect upon the directions of the hills and valleys. A possible exception occurs in the Damúda valley in Bengal; but even this is a disputed case; and the subject will be discussed in the chapters relating to the Gondwána system.

This remarkable absence in the Indian Peninsula of any evidence of disturbance in late geological times—a feature which abruptly distinguishes the whole area from the remainder of Asia—will be further noticed in the sequel: at present it is sufficient to remember that the principal mountain chains of the Indian Peninsula are, with one exception, not coincident with axes of disturbance or elevation, and to note the contrast in the Extra-Peninsular area.

The Arvali differs from the other great ranges of India in being entirely composed of disturbed rocks, with the axes of disturbance corresponding with the direction of the chain. The formations found in the

Arvali range belong to the transition rocks, and are of great antiquity; for the most part they are much altered; they are quite unfossiliferous, and there is evidence which renders it probable that the elevation of the range dates from a period anterior to the deposition of the Vindhyan rocks—themselves of unknown age, but almost certainly not of later date than older palæozoic; whilst the fact that these Vindhyan rocks are found almost horizontal in the neighbourhood of the Arvali range, on both sides of the chain, shews that here, as elsewhere in the Peninsula, the forces which have affected the non-peninsular area in later geological epochs have not been felt.

Mountain ranges of Extra-Peninsular area.—Passing to the other side of the Indo-Gangetic plain—no matter whether the region reached be to the eastward in Sind and the Punjab, to the northward in the Himalayas, or to the eastward in Chittagong and Burma—the mountain ranges, with the exception of a portion of the Assam range, are everywhere composed of disturbed and contorted beds, and the disturbance has invariably affected rocks of late geological age. The amount of alteration may be small or great; the hills may consist of simple anticlinal folds, as in Sind, or of the most complicated inversions, as in parts of the Himalayas; the strike of the bedding may vary from east and west to north and south; but two characters are constant—great disturbance affecting all the formations, and the coincidence of the direction of the ranges with synclinal and anticlinal axes.

Sind and Western Punjab.—In physical characters, as in geology, there is, to some extent, a passage between the two great and contrasting regions in the Western Indian provinces of Guzerat, Kattywar (Kathiawad), and Cutch (Kachh or Kach). These districts are, however, of no great extent, and may be neglected for the present. The rocks of the Eastern Salt Range in the Punjab differ from those of the western extremity, and the former approximate to the Peninsular type. Passing on to the Extra-Peninsular area, and commencing on the west in Sind, there are to the westward of the Indus several ranges having a general north and south direction. Of these, the most important is the Khirthar, forming the western boundary of Upper Sind. But little is really known of the geography west of the frontier. The Hala range of most maps is an imaginary chain of mountains; but there are several ranges immediately to the west of the frontier, parallel to the Khirthar. Farther to the westward, however, the ranges in Baluchistan run east and west parallel with the coast; and to the north of Sind, in the Mari and Bhúgti hills, the same east and west strike is found. These hills are still outside of British territory. The next range to the northward, the Sulemán, form-

ing the boundary of the Punjab, and extending from the frontier of Sind at Kashmor to the neighbourhood of Bannu, is again a north and south range, like the Khirthar. The Northern Punjab is traversed by a series of ranges having a general east and west strike, but being frequently curved, the curvature being greatest in the Salt Range, the most southern of all, and its continuation west of the Indus; whilst the ranges near Peshâwar and Attock are more nearly east and west. But little is known of the mountains in Afghanistan, nor have they much connexion with those of the Indian frontier: a north-east and south-west strike appears to prevail amongst them; but the Safed Koh, forming the southern watershed of the Kabul river, is said to strike east and west, like the Afridi hills and other ranges, of which it is a continuation.

Himalaya.—Throughout the western frontier of India there is a deficiency of rivers, owing to the small rainfall of the country; and no streams of any importance join the Indus from the west. The largest tributary is the Kabul river, which flows past Peshâwar, and runs into the Indus near Attock. The five great tributaries of the Indus—the Jhelum, Chináb, Rávi, Biás, and Sutlej—flow from the Himalayas; and, after traversing the Punjab, unite to form the Punjnad, before falling into the Indus from the eastward. The Himalayas may be considered as extending from the Indus to the Brahmaputra; these two rivers between them almost encircling the mountain zone of Northern India. Both streams rise in Tibet, and within a short distance of each other, and flow, the Indus to the north-west, the Brahmaputra, here known as Sangpo (Sanpoo), first east by south, then almost due east, until each, after a long course, breaks through the Himalayan chain, and reaches the plains of India—the Brahmaputra in Upper Assam, the Indus in the Northern Punjab.

Of the great mountain zone thus defined, the western portion alone is well known; and even here the geology requires much additional study. From a little east of the 80th parallel of east longitude even the geographical details of the Himalaya are but imperfectly represented on maps. The only accessible tract, Sikkim, does not extend far beyond the first great chain, and stops short of the main watershed.

The Himalaya, considered as a whole, forms a curved belt of mountains, with their convexity to the southward, running nearly from north-west to south-east to the westward, and from west to east to the eastward, the eastern extremity striking north of east. But, besides composing a great mountain chain, or series of chains, the Himalayas form the southern scarp of the Tibetan plateau—a tract of highland from about 12,000 to 16,000 feet above the sea. The northern scarp of this plateau is formed

by the Kuenlun, overlooking the lower plains of Eastern Turkestan and the Gobi desert.

The western terminal portion of the Himalayan chain—the only part, as already stated, that has been accurately mapped—comprises a number of great ranges, the majority of which have no settled appellations, but are commonly known by the terms applied to passes through them, or by the names of the districts traversed. The principal of these ranges are the Mustágh, Ladák, Zánskár or Báralácha, and Pir Panjál. The Mustágh, frequently called the Kárákoram, from a well-known pass, which, however, does not cross the range itself, forms the northern watershed of the Indus and its tributary the Shayok, and separates their drainage area from the upper waters of the Yárkand river. To the north-west the Mustágh range appears to curve round into the northeast-southwest chain of the Hindu Kush, and is of great height; its culminating peak, the nameless summit known on the Great Trigonometrical Survey maps as K2, rising to an elevation of 28,278 feet, and being only second to Mount Everest. The Ladák range intervenes between the Indus and Shayok. The Zánskár (Záskár) or Báralácha (Baralatsé) range divides the Upper Indus from the Jhelum and Chináb; the north-western continuation forming the northern boundary of the Kashmir valley, and terminating in the peak of Nanda Parbat. The Pir Panjál divides the Kashmir valley, drained by the Upper Jhelum, from the plains of the Punjab. All these ranges, it should be recollected, have a north-west to south-east direction; and to the westward there is a singularly abrupt change in the strike, as in the instance already mentioned, of the angle formed by the Mustágh range and the Hindu Kush. The angle made by the meeting of the Pir Panjál range, east of the Jhelum, and of the Murree and Hazára hills, west of that river, is even sharper; the latter ranges running at first north and south, forming an acute angle with the Pir Panjál, and then curving round south-west, and finally to west.

It is doubtful whether any of the ranges already noted in the terminal area should be considered the prolongation of the main Himalayan axis, although, if any be really a continuation of the Himalayas proper, it is either the Pir Panjál or the Zánskár range. The main range of the Himalayas appears more probably, so far as geological structure affords a clue, to commence on the westward in the Dhauladhár, a minor ridge rising from the banks of the Rávi close to Dalhousie, and extending to the east-south-east, till it rises into the main snowy range of the North-West Himalayas. Many geographers distinguish two parallel ranges from the neighbourhood of Simla to the eastward: the snowy range

proper, formed of the highest peaks; and a more northern ridge, forming the watershed between the Tibetan plain and the rivers running to the plains of India. Others consider the latter to be the true Himalayan range, and look on the higher peaks as belonging to the spurs between the rivers flowing from that range. It is certain that the great peaks, such as Nanda Devi (25,700 feet), Dhaulagiri (26,826 feet), Mount Everest (29,002 feet), Kinchinjinga (28,156 feet), Chumalari (23,929 feet), &c., are separated from each other by deep valleys through which flow streams coming from the northern range, and that, although the peaks of the latter are inferior in elevation, the passes by which it is traversed are much higher; but it has not yet been ascertained whether the great peaks are on the strike of any continuous band of rock, or whether they merely consist of hard nuclei left undenuded.

Along the southern base of the Himalayas, and parallel with the general direction of the mountains, a series of comparatively low ridges extends, formed of tertiary rocks, and separated from each other or from the rocks of the main range by valleys called dúns. These fringing ranges of the later formations are known generally as the Sub-Himalayas; the most important being the Siwalik hills, a term especially applied to the hills south of the Deyra Dún, but frequently employed in a wider sense than its original application. To the eastward, the Sub-Himalayan ranges are less conspicuous than to the westward; but they are only locally wanting altogether, and are to be traced almost throughout the Himalayan border, from the Punjab to Upper Assam. The rivers running from the Himalayas to the Ganges and Bráhmaputra, although in many cases of considerable size, are in general formed by the union of a number of comparatively unimportant hill streams; the largest and best known of these rivers, beginning from the west, are the Gogra (Ghogra), Gandak, Kosi (Koosee), and Tista (Teesta).

Ranges and rivers of Burma, &c.—The hills immediately south of the Bráhmaputra belong to two distinct systems. The chain, known collectively as the Assam range, and locally as the Gáro, Khási (Khasia or Cossya), Jaintiá (Jyntia), and Nága hills, runs east and west to the westward and turns to north-east to the eastward, being nearly parallel to the Himalayas throughout. The western part of this range, like the hills of Kattywar and Cutch to the west of the Peninsula, presents a remarkable combination of peninsular and extra-peninsular rocks. It will be shewn that in this direction also some of the peninsular formations are found at the base of the Himalayas; but the peculiarity of the Gáro and Khási hills is, that there is less marked coincidence between the strike of the newer rocks and the direction of the range than in the

extra-peninsular area generally. To the eastward, in the Nága hills, the usual connexion between the strike of the rocks and the direction of the ranges reappears; and a monoclinal axis may be traced along the southern face of the Jaintiá, Khási, and Gáro hills themselves; but the greater portion of the latter form a plateau, on which the mesozoic and tertiary formations are horizontal, or nearly horizontal. The most important ridge of the Nága hills is the westernmost portion, known as the Barail-Pátkai range; and this chain is distinctly cut off from the western plateau of the Assam range by an abrupt change of dip in the rocks, and geographically by deep valleys.

The Súrma (Soorma) or Bárak river drains the southern slopes of the Assam range, and divides it from the great hill region of Burma. In North-Eastern Manipur (Muneepoor) there is a transition from the north-east—south-west strike of the Nága hills to the north and south (or north-by-west to south-by-east) direction of the Burmese mountain chains. The north and south direction is nearly constant throughout British Burma, and continues, curving to the south-east, in the Malay Peninsula. The great Burmese rivers, the Irawadi and Salwin, and the less important streams, the Sittoung, Tenasserim, &c., ran from north to south; and the principal hill ranges are the Arakan Yoma, between the Irawadi and the sea; the Pegu Yoma, between the Irawadi and Sittoung; and a number of less defined chains, formed of older rocks, east and west of the Salwin and throughout the Tenasserim provinces. None of these ranges within British territory attain a height exceeding 7,000 feet.

Geological formations in general.—After the above brief sketch of the more conspicuous geographical features of India and the surrounding countries—a sketch in which one of the most important distinctions between the peninsular and extra-peninsular areas has been pointed out—it will be well to proceed at once to a comparison of the geological formations found in the different regions. The contrast here will be found quite as great as in the case of the physical geography. Throughout the peninsular area, there is, from the lowest to the highest formation, a most remarkable deficiency of fossiliferous marine rocks; the few that occur being almost exclusively found in the neighbourhood of the present coast, or else in the desert between the Arvali chain and the river Indus. With one solitary exception—that of some cretaceous beds occupying a limited area in the Narbada valley—no instance is known of marine fossils being found in the Indian Peninsula, to the south-east of the Arvali range, at a greater distance than 70 miles from the coast.

The absence of marine fossils is certainly not due to the alteration the strata have undergone, nor to the deficiency of rocks suited for the

preservation of organic remains. Land and freshwater organisms are found in considerable quantities in some of the mesozoic and cænozoic formations; and it is possible that the lowest fossiliferous Gondwána beds may be of upper palæozoic age. Even at a lower horizon, in the ancient Vindhyan formation, limestones and shales, to all appearance perfectly adapted for the preservation of fossils, occur in profusion; and it is surprising that no trace of organic remains has ever been detected in the transition series, many of the slates, shales, and limestones being no more altered than some of the older fossiliferous beds of Europe, and even of the Himalayas. When it is recollected how long the "grauwacke" of Western Europe was supposed to be unfossiliferous, some faint hope may still survive that fossils may yet be found in the Vindhyan and transition rocks of India; but the European Silurian and Cambrian beds yielded organic remains in abundance to the first attempt at systematic exploration; whilst the Vindhyans, Bijáwars, Kadapahs, Karnuls, and other ancient Indian formations have been searched repeatedly, but without success, by experienced geologists, who had throughout their lives been engaged in similar researches. It cannot be said that the search is hopeless, in the Upper Vindhyans especially; but it may fairly be doubted whether any conspicuous marine organisms, such as mollusca, corals, or crustacea, will be detected.

Of the few marine beds hitherto found in the Indian Peninsula, none are older than jurassic. Even the jurassic marine beds are well represented only in Cutch and the neighbouring countries, the known representatives of the series on the eastern coast of the Peninsula being but poorly developed. The cretaceous marine rocks are better represented; although a considerable portion of the series is wanting, and the area occupied is very small. The marine beds of the tertiary period are also, so far as is known, very ill-developed, or wanting, except in Guzerat and Cutch.

In the extra-peninsular area, on the other hand, marine fossiliferous rocks of silurian, carboniferous, triassic, jurassic, cretaceous, eocene, and miocene age have been found; and in many cases a complete sequence of the different sub-divisions of each epoch has been detected; although far less time and labour have been devoted to the examination of the country than have been given to the Peninsula, and although the geology of the area is in general much more complicated, and the task of surveying surrounded by greater difficulties.

List of peninsular formations.—The following is a classified list of the formations in the Indian Peninsula, inclusive of Kattywar and Cutch. The great European sub-divisions of the geological sequence—palæozoic, mesozoic, and tertiary or cænozoic—are ill adapted for the classification of

the Indian beds; and in several instances, as will be shewn more fully in other chapters of this work, the correlation of the strata found in the Peninsula of India with the geological series elsewhere is far from satisfactorily decided. The lower formations in this list are simply classed as azoic. The sub-divisions are not always strictly consecutive; some of the marine cretaceous rocks being of the same age as the Deccan traps, and the marine jurassic beds being contemporaneous with the Upper Gondwánas.

Classified List of Formations in Peninsular India.

	Formation			*Approximate maximum thickness.*
	Recent and post-tertiary.		Blown sand. Soils, including black soil or regur. Modern alluvial deposits of rivers, estuaries, and the sea coast. *Khádar* of Indo-Gangetic plain, &c. Raised shell beds of coast. Low-level laterite. Older alluvial deposits of Ganges, Narbada, Godávari, &c. Cave deposits.	Unknown; 700 feet deepest boring.
Cænozoic.	Tertiary .		Miliolite of Kattywar. Pliocene, miocene, and eocene (nummulitic) beds of Cutch and Guzerat. Sandstones, clays, and lignites of the west coast, Travancore and Ratnagiri. Cuddalore sandstones. High-level laterite.	2,700
Cænozoic. / Mesozoic.	Deccan trap series.		Upper traps and intertrappeans of Bombay. Middle traps. Lower traps and intertrappeans of Central India, Rájámahendri, &c. Lameta or infratrappean group. Infratrappeans of Rájámahendri.	6,000
Mesozoic.	Marine cretaceous rocks.		Arialúr, Trichinopoly, and Utatúr groups. Bágh beds. Neocomian of Cutch.	3,000
Mesozoic.	Marine jurassic rocks.		Umia, Katrol, Chári, and Pachham groups of Cutch. Jesalmir limestones. Tripetty and Ragavapuram beds of east coast.	6,000
Mesozoic.	Gondwána system.	*Upper*	Cutch and Jabalpur. Rájmahál and Mahádeva.	11,000
Palc.?	Gondwána system.	*Lower*	Panchet. Damúda:—Ráníganj or Kámthi, ironstone shales, and Barákar. Karharbári and Tálchir.	13,000
Azoic.	Vindhyan series.	*Upper*	Bhánrer (Bundair). Rewah. Kaimur (Kymore).	12,000
Azoic.	Vindhyan series.	*Lower*	Karnul. Bhima. Son. Semri. . . .	2,000 ?
Azoic.	Transition or sub-metamorphic rocks.	*Upper*	Gwalior, Kadapah, and Kaladgi series . .	20,000
Azoic.	Transition or sub-metamorphic rocks.	*Lower*	Bijáwars. Chámpanir beds. Arvali. Maláni beds. Transition rocks of Behar and Shillong (the last extra-peninsular).	
Azoic.	Metamorphic or gneissic.		Gneiss, granitoid and schistose rocks, &c. . . .	?

The following is the succession of the more important fossiliferous peninsular rocks, the marine beds being omitted from the sequence, but classed as equivalent to their supposed representatives amongst the formations without marine fossils :—

		Peninsular rocks.	*Supposed marine equivalents.* Indian.	European.
CÆNOZOIC		High-level laterite . .	Nummulitic	Middle eocene.
	DECCAN TRAPS.	Upper Deccan traps .	?	Lower eocene.
MESOZOIC		Middle traps Lower traps Infratrappeans or Lameta	Arialúr Trichinopoly Bágh beds, Utatúr.	Upper chalk. Lower chalk. Upper greensand.
	GONDWÁNA.	Jabalpur and Cutch. Mahádevá and Rájmahál	Umia and Katrol. Chári and Pachham.	Jurassic.
		Panchet		Triassic.
PALÆOZOIC		Damúda . . . Tálchir . . .	. . . .	Upper palæozoic ?

It will be seen at once that the geological horizon of the upper mesozoic and tertiary beds is ascertained with a fair amount of precision; but that the determination of the position in the series to be assigned to the Lower Gondwána formations is far more doubtful, and that nothing is known of the age of the Vindhyans and older rocks.

List of Extra-Peninsular formations.—Owing partly to imperfect knowledge of the ground, but still more to the extent to which the different tracts of Extra-Peninsular India comprised in British territory are isolated and separated from each other by such regions as Nepál and Afghanistan, entirely inaccessible to Europeans, the correlation of the various formations in the extra-peninsular region with each other is more imperfect than in the peninsular area. This circumstance, however, in no way affects the contrast between the rocks in the two areas. The interstratification in Kattywar and Cutch of certain peninsular formations with marine beds belonging to the extra-peninsular types has already been noticed; but the geology of Kattywar is as yet but imperfectly known, and the only peninsular formations found in Cutch are of newer mesozoic or tertiary age. A thin representative of the Deccan trap is also found in Sind. At the eastern end of the Salt Range in the Punjab are found several groups of unfossiliferous sandstones, having some resemblance in general character to the Gondwána and Vindhyan systems of the Peninsula; and as the age of some of the Eastern Salt Range groups is approximately determined by the interstratification amongst

them of beds representing the fossiliferous marine rocks of the western portion of the range, some clue may perhaps here be afforded to the age of the peninsular rocks. Hitherto, however, no such clue has been obtained; the Salt Range is at a considerable distance from all the Gondwána and Vindhyan rocks of the Peninsula, and none of the unfossiliferous Salt Range groups has as yet been identified with any of the peninsular formations.

With the exception of Sind, there are but two localities in Extra-Peninsular India where peninsular rocks are found. One of these is at the base of the Himalayas, in Sikkim and Bhután, where fossiliferous Damúda (Lower Gondwána) beds occur. The other is in the Assam hills (Khási and Gáro), where representatives of the metamorphic and cretaceous (marine) rocks of the Peninsula, and in all probability of the transition beds and of the Rájmahál traps, are found. But, in the first instance, the relations between such Himalayan rocks as are associated with the Damúdas and those of other parts of the Himalayas are extremely doubtful; and it is not even conclusively settled whether the Himalayan rocks in question are higher or lower in position than the Damúda beds themselves; and in the Assam hills none of the older Himalayan formations have been detected: they appear to be replaced by peninsular types.

Of the extra-peninsular rocks two lists are given below: in the first, the representatives of different geological horizons in the various tracts are enumerated; and in the second, an attempt has been made to exhibit the probable correlation of the rocks in the different parts of the area, so far as the information available extends. In both lists, an asterisk serves to shew that a formation is unfossiliferous, and a note of interrogation that the position is doubtful.

CLASSIFIED LIST OF FORMATIONS IN EXTRA-PENINSULAR TERRITORIES BELONGING TO INDIA.

RECENT AND POST-TERTIARY. Alluvial and lake deposits. Sub-Himalayan high-level gravels.*

PLIOCENE. Upper Manchhars of Sind. Upper and middle Siwaliks of Sub-Himalayas, Punjab, &c. Mammaliferous deposits of Western Tibet. Dehing group* of Assam. Fossil-wood deposits of Pegu.

MIOCENE. Lower Manchhars and Gáj of Sind. Murree beds* (in part). Náhan.* Tipam group of Assam?* Pegu group of Burma.

EOCENE .	*Upper* .	Nari group of Sind. Kasauli and Dagshai* groups of Sub-Himalayas.
	Middle .	Nummulitic limestone of Sind, Punjab, Assam, Burma, &c. Khirthar of Sind. Subáthu of Sub-Himalayas. Indus or Shingo beds of Western Tibet. Coal-measures of Assam ?
	Lower .	Ranikot beds of Sind. Lower nummulitics of Salt Range.
CRETACEOUS .	*Upper* .	Deccan trap.* *Cardita beaumonti* beds and cretaceous sandstones of Sind. Olive group of Punjab Salt Range. Disang group* of Assam ? Upper cretaceous of Khási Hills. Negrais beds of Burma ? (*N.B.*—It is not certain that some of these formations may not be, in part at least, eocene.)
	Middle .	Hippuritic limestone of Sind. Cretaceous beds of Mount Sirban in Hazára and of Kohát. Chikkim beds of North-Western Himalayas. Cretaceous beds of Assam, in part. Mai-i group of Burma.
	Lower or *Neocomian*.—	Beds in Chicháli Pass, Salt Range.
JURASSIC .	*Upper* .	Salt Range. Gieumal and Spiti beds of Northern Punjab and North-Western Himalayas.
	Middle .	Variegated group of Salt Range. Part of Spiti shales in North-Western Himalayas ?
	Lower or *Lias*.—	Upper Tagling limestone of North-Western Himalayas. Sylhet trap ?*
TRIAS .	*Upper including Rhætic*.—	Lower Tagling limestone of North-Western Himalayas. *Nerinæa* beds of Mount Sirban, Hazára. Pára limestone of North-Western Himalayas. Beds with *Megalodon* and *Dicerocardium* at Mount Sirban, Hazára.
	Middle .	Salt Range ? Liláng series of North-Western Himalayas and Kashmir. Axial group of Burma ?
	Lower .	Ceratite beds of Salt Range. Infra-triassic* of Hazára, in part ?
PERMIAN & CARBONIFEROUS.		Salt Range carboniferous limestone. Damúdas of Sikkim and Bhután ? Infra-triassic* of Hazara ? Kiol limestone* of Pir Panjál ? Król* limestone and Infra-Król* of Western Himalayas ? Kuling series of North-Western Himalayas and Kashmir. Maulmain group of Burma.
SILURIAN .		*Obolus* beds of Salt Range. Attock slates* of Upper Punjab ? Slates* and traps* of Pir Panjál and Kashmir? Muth and Bhábeh series of North-Western Himalayas. Blaini* and Infra-Blaini* of Simla area ?
INFRA-SILURIAN.		Salt marl* of Salt Range ? Gneiss* of Pir Panjál and Ladák. Upper gneiss* of Záuskár range. Shillong series* of Assam hills ? Mergui group ?*
		Lower or central gneiss* of Himalayas. Gneiss* of Assam and Burma.

The thickness of the different formations has only been determined in a few instances; so few that it is useless to quote them. The amounts are very great, the tertiary rocks alone attaining a vertical development in places, as in Sind, of nearly 30,000 feet.

DISTRIBUTION OF EXTRA-PENINSULAR FORMATIONS.

	Sind.	Punjab Salt Range.	Northern Punjab.	N. W. Himalaya and Tibet.	Lower Himalaya and Sub-Himalaya.	Assam.	Burma.
Pliocene	Manchhar	Siwalik	Siwalik	Mammaliferous beds...	Siwalik	Dehing group*	Fossil-wood group.
Miocene	Gáj	......	Murree beds*	......	Nahán*	? Tipam group*	Pegu group.
Eocene	Nari	......		......	Kasauli & Dagshai*	Nummulitic and coal-measures.	Nummulitic.
	Khirthar	Nummulitic	Nummulitic	Indus or Shingo beds	Subáthu		
	Ranikot	Lower Nummulitic	?	......	......	......	......
Cretaceous	Deccan trap* Olive shales & sandstones.	Olive group	?	......	......	? Disang group*	? Negrais group.*
	Hippuritic limestone.	......	Cretaceous of Mount Sirban and Kohát.	Chikkim beds	......	Cretaceous	Mai-i-group.
	......	Neocomian	......	......	......	......	......
Jurassic, *including* Lias.	......	Upper Jurassic	Upper Jurassic	Gieumal sandstones	......	......	......
	......	Middle Jurassic (Kelloway).	?	Spiti shales.	......	......	......
	......	......	......	Upper Tagling limestone.	......	Sylhet trap*	......
Triassic, *including* Rhætic.	......	......	*Nerinæa* beds	Tagling limestone	......	......	......
	......	......	Upper trias of Mount Sirban.	Pára limestone	......	......	......
	......	Middle trias	......	Liláng series	......	......	Axial group.
	......	Lower trias	? Infratriassic & Tanol*	?	? Damúdas	......	......
Carboniferous	......	Carboniferous limestone.	......	Kuling series and ? Kiol limestone.*	? Król* and Infra-Król.*	......	Maulmain series.
Silurian	......	......	......	Muth series	? Blaini*	......	......
	......	*Obolus* beds	? Attock slates*	Bhábeh series	? Infra-Blaini*	......	......
Infra-Silurian	......	? Salt marl*	Metamorphic*	? Upper gneiss*	......	? Shillong series*	? Mergui series.*
	......	......	......	Lower or Central gneiss.*	Gneiss*	Gneiss*	Gneiss.*

Summary of geology.—With these data before us, we may proceed to a brief summary of the geological history of India. This summary will serve to shew that, despite the imperfection of the geological series developed in the Peninsula, there is evidence of a singular permanency of conditions and freedom from severe disturbance at all periods after early palæozoic times. Up to the tertiary epoch the same absence of contortion appears to have prevailed in the extra-peninsular area also, but in later geological times extensive disturbance has affected many parts of the latter country. In this summary, it will be necessary frequently to anticipate arguments used in the succeeding chapters, in which, however, fuller details will be given.

Although, as has already been said, no marine fossils of older date than jurassic have been found in the Indian Peninsula, it by no means follows that the ancient azoic rocks are not of marine origin. All that can be said of the peninsular gneissic and transition series is, that they are ancient sedimentary beds: whether deposited in the sea or in rivers or lakes, it is impossible to tell. The rocks of these formations may have been originally fossiliferous; for the amount of alteration they have undergone would have sufficed in many cases to obliterate all traces of organic remains; but the absence of fossils in the much newer Vindhyans is not so easily explained; and even some of the transition beds are not more altered than rocks in which fossils have elsewhere been detected.

Metamorphic rocks.—The gneissic rocks of the Indian Peninsula are developed in three areas—the peninsular area proper, comprising the greater portion of Bengal and Madras, the Bundelkhand, and the Arvali—and appear to include representatives of two formations at least, differing in age. The older, which will be described as the Bundelkhand gneiss, is shewn to be more ancient than the gneissic formation throughout the greater part of India, by the circumstance that certain transition rocks rest without alteration and unconformably on a denuded surface of the former, but are altered and intersected by granitic intrusions in the neighbourhood of the latter; so that there is to all appearance a passage between the transition beds in question and the peninsular gneiss. It is manifest that the Bundelkhand gneiss was altered before the deposition of the Bijáwar transition rocks, and it appears probable that the peninsular gneiss was metamorphosed after Bijáwar times; and it is a reasonable inference that the peninsular gneiss, whether composed of altered Bijáwar rocks or not, is the later of the two gneissic series in origin as well as in period of metamorphism. The relative age of the gneiss occupying the Arvali area in Rájputána is uncertain.

There are no data known by which the relations of the oldest Himalayan rocks to the metamorphic formations of the Peninsula can be determined. There is a well-marked mineralogical distinction between the older gneiss of the Himalayas and both of the peninsular types—that of Bundelkhand and that of the Peninsula proper. The most important differences are, that the Himalayan gneiss is usually white or grey, the common felspars being orthoclase and albite, whilst the ordinary peninsular gneiss is pink, the prevailing felspars being orthoclase and oligoclase; and that the former rock is more micaceous, whilst the latter contains more hornblende. The Himalayan gneiss, too, is, as a rule, more uniform in character; it contains far more mica schist, but less quartzite, and very little hornblendic or syenitic gneiss; whilst in the peninsular forms of the rock the different beds vary greatly in mineral characters, and a highly hornblendic variety is much more prevalent than mica schist.

The metamorphic rocks of the Assam hill range belong, as has already been mentioned, to the same mineralogical type as the Bengal gneiss; and hills of this rock are found in places rising out of the alluvium of the Assam valley, close to the base of the Himalayas. The gneissic rock of Assam and that of the Himalayas are nowhere seen in contact; but the distinction in mineralogical character is absolute. In the absence of any contact-section there is, however, no clue to the relative age of the two series: it is impossible to say whether the Himalayan gneiss is older than that of the Peninsula, or *vice versâ*. It should also be recollected that the gneiss of the Western Himalayas is divided from that of the mountains north of Assam by nearly 500 miles of unexplored country in Nepál.

The contrast between the peninsular aud extra-peninsular regions begius thus with the oldest known rocks; but it is evident that the limits of the areas were then different from what they subsequently became. Not only are the metamorphic formations of the Assam hills similar to those of the Peninsula, but the gneiss of Burma resembles the peninsular type rather than the Himalayan.

Although the metamorphic rocks are frequently granitoid, true granite only occurs amongst them in the form of veins; no large areas are known. Granitic intrusions are of larger dimensions in the older submetamorphic or transition rocks than in the gneissic series.

Transition rocks.—The transition or submetamorphic rocks of India consist of schists, slates, quartzites, breccias, limestones, &c.; they occupy a considerable area, and attain a very great thickness, but their history is as obscure as is that of the gneiss. They have been classed in two

sub-divisions: the first, which is supposed to be the older, exhibiting by partial metamorphism, conformable sequence or granitic intrusion, a close connexion with the gneissic strata; the second, shewing no such relation. The transition rocks are also divided into several groups, distinguished as much by locality as by mineral characters. All these details will be found in the second and third chapters of the present work: the only points of importance to be now noticed are the relations between the transition series, as a whole, and the older and newer rocks of the Peninsula.

The most important of these relations may be summed up in the fact that some of the transition beds appear to have been deposited previously to the last great disturbances that affected the strata of the Peninsula; whilst later beds, when tilted or contorted, are only affected within limited areas. Faults of considerable magnitude have certainly been formed at a subsequent period; but still the great lines on which the rocks of the Peninsula have been moulded were more than traced before the transition epoch had passed away: they were so firmly laid down, that they have determined the main features of the land, wherever these are dependent on the strike of the rocks; and it is remarkable how often the minor disturbances of a later date conform to the direction of the foliation in the metamorphic rocks. For although, with the exception of the Arvali, the great ranges of the Indian Peninsula appear almost solely due to the action of denudation, and although the direction of these ranges is independent of the strike of the newer rocks of which the hills themselves are composed, many of the minor ranges and of the smaller river valleys coincide in direction with the foliation of the gneiss, or the stratification of the older transition rocks. It matters little whether the gneiss foliation be due to bedding or cleavage: if the former, the high angles are evidence of great lateral pressure; if the latter, the very existence of cleavage proves the same; and the parallelism of the foliation throughout large areas, and sometimes over hundreds of miles, as in the Narbada valley, shews how extensive were the disturbing causes to which this uniformity of result is due. It is far from improbable that great mountain ranges were formed in the Indian Peninsula before the dawn of geological history, as recorded by organic remains, and that the small ridges of metamorphic and transition rocks now remaining are but the remnants that have escaped denudation.

It is difficult to say how far the eruption of igneous rocks is connected with areas of disturbance: the problem has not yet been solved. Independently, however, of the granitic intrusions already noticed, igneous rocks, often to all appearance of contemporaneous origin, are almost everywhere associated with the transition strata. Diorite or an allied

rock, often greatly altered, is found in the Shillong transition series, the beds of Chutia Nágpúr (Chota Nagpore), the Bijáwars of Bundelkhand and the Narbada valley, the Gwalior, Arvali, and Chámpanir beds, and the Kadapah (Cuddapah) series; whilst the Maláni transition beds are chiefly composed of felsites. Many of the "trappoid" rocks associated with the various transition strata, to judge by the descriptions given, have the characters of altered subaqueous volcanic tuffs; and this may indicate that the associated transition beds are of marine or lacustrine origin. In fluviatile, as in other subaërial deposits, the character of the associated volcanic rocks would probably be different. Some of the transition igneous rocks, however, have not the characters of subaqueous tuffs.

Vindhyan series.—The break between the uppermost transition beds and the quartzite sandstones, shales, and limestones of the Lower Vindhyans does not appear to be very great; for although the two series are nearly always unconformable, where the newer is seen to rest upon the older, there are several obscure sections indicating passage; and in the Godávari valley it has hitherto proved impracticable to distinguish the limits of the two series with certainty. The Vindhyans, however, and especially the Upper Vindhyans, have a far more recent aspect than the transition rocks: a distinction due doubtless to the much smaller amount of disturbance, and consequent alteration experienced by the newer series. It is an exception to find the Vindhyans, upper or lower, dipping at high angles; and over large areas these rocks are nearly horizontal.

The thickness of 2,000 feet assigned as a maximum to the Lower Vindhyans is probably too little; but still they are far inferior in development to the underlying transition beds and to the overlying Upper Vindhyans. It is the more surprising on this account to find that the Lower Vindhyans have so great a horizontal extension, and that they are found, with but small change in mineral character, from the Son valley to Kadapah in one direction, and to the neighbourhood of Bijápúr in another, a distance in each case of 700 miles. In the Son area, too, some peculiar beds of trap-like rock occur, similar to those already noticed as being intercalated in the transition series of Gwalior, Kadapah, and other places, and as having the characters of subaqueous volcanic tuffs. These facts are in favour of the marine origin of the Lower Vindhyans. But, on the other hand, the area occupied by this series is not continuous; and in one locality at all events, south of the Son valley, there are indications of an ancient barrier between different basins of deposition, whilst the singular absence of organic remains is rather in favour of freshwater origin; freshwater beds being, as a rule, less fossiliferous than

marine. At the same time, there is always a possibility that these formations may have been deposited at an epoch anterior to the existence of life; although, in face of the great probability that the earliest forms of organised beings existed long anterior to the appearance of *Brachiopoda* and *Crustacea* in the Cambrian formation, and even of *Foraminifera* in the Laurentian, the likelihood of the Vindhyans dating from a time when the world was devoid of life appears small. It is possible that the tropics were too hot for life, even after the polar regions and temperate zones were inhabited; but this is open to question on physical grounds, and appears contradicted by the similarity of silurian fossils in the southern hemisphere to those in the northern. Had life originated independently in both hemispheres, a wide divergence of forms might have been anticipated in the earlier formations between the two areas on opposite sides of the equator. At the same time, it is quite possible, and even probable, that marine life existed long before the fresh waters and the land were inhabited; and the land and fresh waters of the tropics may have been too hot for animals or plants after the sea teemed with living beings. Unfortunately, the first element of the question,—the enquiry whether the direction of the earth's axis has been constant, and consequently whether the present tropics have always been in the neighbourhood of the earth's equator,—has not been decided by mathematicians; and it will be shewn presently that there are some very curious indications of a low temperature having prevailed in the Indian area at very ancient epochs.

The Upper Vindhyans, consisting chiefly of fine, hard, red sandstone, with subordinate bands of shale and limestone, are quite parallel, and apparently conformable, to the lower, as a rule; but still there is extensive overlap of the lower by the higher series, and some amount of local unconformity, shewn by the presence of detritus, derived from the older beds, in the conglomerates of the newer. The area of the Upper Vindhyans is almost restricted to the great tract extending from Behar to the Arvali hills; and differs so greatly from that of the Lower Vindhyans, that a great change probably took place in the area of deposition in the interval between the formation of the two; whilst there is much in the peculiar conditions of the rocks, and in the features of the boundary, to indicate that the Upper Vindhyans may have been deposited in a land-locked area. The persistent red colour of the Vindhyan sandstones may perhaps also indicate deposition in an inland basin; for although Professor Ramsay's views on the subject[1] are not universally conceded, there can be no doubt that the old and new red sandstones of England, and

[1] Q. J. G. S., 1871, pp. 197, 241.

many similar rocks elsewhere, were in great part formed in lakes or lagoons, and not in an open sea. The same observation applies, though less generally, to the Lower Vindhyans and many of the transition rocks; several of the beds, and especially the sandstones or quartzites, having the same red colour as the Upper Vindhyans.

It has already been intimated that the elevation of the Arvali probably dates from pre-Vindhyan times; and the supposed Vindhyan rocks of Jodhpur to the west of the Arvali, if really of contemporaneous age with the main area of Upper Vindhyans, may have been deposited in a second basin.

It is not possible, in the absence of fossils, to express any decided opinion as to whether the Upper Vindhyans are of marine or freshwater origin. The prevalence of sandstones, the subordinate character of the limestones, the approximate limitation to a defined, although extensive, tract, the want of fossils, and, considering the probability that the series was deposited in an inland basin, the absence of any deposits of salt or gypsum,—are all in favour of freshwater origin; but it cannot be said that these arguments are conclusive. The frequent occurrence of rippling on the shales and finer sandstones indicates that the rocks are shallow-water deposits. No contemporaneous igneous rocks are known.

The Vindhyans are the latest azoic rocks of the Peninsula. So far, there is no indication of any defined geological horizon. The complete severance between the Vindhyans and the Gondwánas, the next series in ascending order, prevents the deduction of any inference from the latter as to the age of the former. The only clue to the magnitude of the break is furnished by the relations between the Gondwánas and the azoic slates of the Sikkim Himalayas. The details will be found in Chapter XXV. The evidence is too uncertain to be accepted with much confidence; but, so far as it goes, it is in favour of the Vindhyans being classed as very ancient, and perhaps as pre-silurian.

Probable conditions of deposit.—From such data as have been hitherto afforded but little can be inferred as to the history of the Peninsula in pre-Vindhyan periods. The peculiarities exhibited by the various local groups of transition rocks are in favour of deposition in isolated areas, and consequently of a considerable proportion of the country having been above the sea; and there is even a greater probability, that India was a land area, or part of a land area, in Upper Vindhyan times than in the previous eras. The great break which succeeds the Vindhyan age may mark an extensive and prolonged period of terrestrial conditions. For any indication of the history of the country in early palæozoic times, we must leave the Peninsula, and turn to the Punjab and

the Himalayas. The oldest beds to the eastward, in Burma, are too little explored to afford information, and, so far as they are known, they present no marked distinction from the peninsular rocks; whilst the metamorphic and transition formations of the Assam hills are similar to those of Bengal. Along the western frontier, in the Punjab and Sind, no old beds are known; and proceeding to the northward, the first palæozoic rocks exposed at the surface within Indian limits are in the Salt Range of the Punjab.

Palæozoic rocks of Salt Range.—In this Salt Range there is a very remarkable and interesting phenomenon. At the eastern termination of the range almost all the older rocks consist of unfossiliferous sandstones, whilst to the westward marine rocks containing fossils prevail. The very oldest formation, however, is destitute of fossils throughout the range; and the most ancient form of life occurs near the eastern end of the hills. The idea, suggested by Dr. Waagen, that the Salt Range marks a portion of the limit of the ancient peninsular land, is highly probable; but the evidence of the replacement of marine formations to the westward by unfossiliferous sandstones, indicating freshwater or terrestrial conditions to the eastward, begins with the carboniferous period.

The oldest group of the Salt Range is a bed, at least 1,500 feet thick in places, of bright-red marl, with thick beds of rock-salt and gypsum. This is succeeded in ascending order by from 250 to 450 feet of deep purple sandstone, and then comes the lowest band containing recognisable fossils—a belt of black shale with calcareous layers. In the two lower groups only obscure and indistinct traces of fucoids and markings resembling annelid burrows have been detected; but in the shale Mr. Wynne obtained a small brachiopod closely resembling *Obolus*. This probably indicates marine conditions and a lower palæozoic horizon. Above the shale comes another unfossiliferous bed, the "magnesian sandstone," a pale-coloured sandy dolomite, about 200 feet thick. At the east end of the range this is succeeded by bright-red clays and flaggy sandstones, and then come upper mesozoic or tertiary rocks. Various changes take place in the series farther west, and it is by no means certain how far the formations at the two ends of the range represent each other; but to the westward the various unfossiliferous sandstones die out, and the salt marl is immediately overlaid by carboniferous limestone, with the typical fossils, *Productus*, *Spirifera*, &c. It is clear that there must be a great break in sequence between the salt marl and the carboniferous limestone; for several hundred feet of sandstones intervene between the two, where the limestone first makes it appearance in the

middle of the range; and the salt marl is in all probability of silurian age at the latest.

The red marl, with thick beds of salt and gypsum at the base of the section, can scarcely have been formed otherwise than in an inland basin: whether in partial or occasional communication with the sea or not it is, of course, impossible to say. The interstratification of the *Obolus* band with the unfossiliferous sandstones very probably indicates alternation of marine and terrestrial conditions; and in upper palæozoic times the sea evidently occupied the region now forming the western portion of the range. But the fossils of the Salt Range carboniferous limestone are in many cases the same as those found in Europe, in America, and in Australia; and to the westward and northward, similar limestone, with the same shells, is found in the Sulemán range and in Kashmir, and far to the eastward, in the trans-Himalayan area; so that it is a reasonable inference, that the sea in which the carboniferous limestone of the Salt Range was deposited was part of the great ocean. At the same time if, as appears probable, some of the sandstones to the eastward are of contemporaneous origin with the upper palæozoic limestone of the Western Salt Range, the existence of a coast line is indicated, even if the sandstone beds be not of freshwater origin; for many conglomeratic bands occur.

Oldest rocks of Northern Punjab, Kashmir, &c.—Farther to the north in the Punjab, in the neighbourhood of Attock and of Abbottabad in Hazára, the oldest unaltered rocks are unfossiliferous slates, with some limestones, and occasional bands of basic volcanic rocks, perhaps contemporaneous. In Hazára, near the Indus, metamorphic rocks occur; but their relations to the slates are not determined with certainty, the one being possibly in part an altered form of the other. The carboniferous limestone has not been found in place in the extreme north of the Punjab; but some mesozoic beds overlying the Attock slates are related to Himalayan rocks of the same age; and farther to the eastward, in Northern Kashmir, and other parts of the North-West Himalayas, similar mesozoic rocks rest upon carboniferous limestone; and this last is succeeded in descending order by a great mass of slates, sandstones, quartzites, &c., resting, in turn, upon gneiss. In Kashmir itself and its neighbourhood no fossils have been found below the carboniferous formation; but farther to the south-eastward, in Spiti, two fossiliferous bands, the Bhábeh and Muth beds of Stoliczka, have been detected, both probably of silurian age. Still farther east, too, in the north of Kumaun, silurian fossils have been discovered in considerable quantities. There is reason for believing that the Attock slates are a continuation to the westward of the slates of Lahúl,

Kishtwár, and Kashmir; that the latter are representatives of the silurian rocks of Spiti and Kumaun, and that the whole of these rocks are marine. Contemporaneous traps are associated with these silurian formations both in Spiti and Kashmir, and may in great part be of subaqueous origin; though the amygdaloidal eruptive rocks of the Kashmir valley rather resemble subaërial lava flows in some respects. On the whole, the probabilities are in favour of marine conditions having prevailed throughout the extreme north of the Punjab, Kashmir, and the neighbouring countries north of the Dhauladhár and main Himalayan range in lower palæozoic times.

Oldest rocks of Himalaya.—The formations in the Western Himalayan area of earlier age than silurian are quite unfossiliferous and much altered. They consist of gneissic rocks of two ages: the central gneiss of Stoliczka, and a newer series resting upon the older, and passing upwards into the silurian slates, which are shewn to be unconformable to the older gneiss by containing large quantities of fragments derived from it. Neither of these forms of gneiss affords any distinct clue to the conditions under which it was originally deposited; but the newer probably consists of altered marine beds.

It has already been intimated, that the marine palæozoic formations already noticed are found to lie north of the main Himalayan axis, the great range of crystalline rocks forming the snowy range north of Simla, and terminating apparently in the Dhauladhár. South of this range, resting upon the ancient gneiss in the neighbourhood of Simla, and elsewhere, is a series of schists, quartzites, sandstones, shales, limestones, &c., in which no fossils are known to have been found; some supposed discoveries of mesozoic and tertiary shells amongst these beds having too many elements of doubt to be recognised as authentic. These rocks are known in ascending order as the Infra-Blaini, Blaini, Infra-Król, and Król beds; and they have been supposed by various observers to represent the trans-Himalayan formations in different ways. The most conspicuous band is a massive limestone—the Król limestone of the Simla region. This rock has been traced for a considerable distance both eastward and westward, and was for some time by Dr. Stoliczka supposed to represent the triassic formation of Spiti; but a more probable representative has been recently indicated by Mr. Lydekker in the limestone of the Pir Panjál, believed on fair evidence to be of carboniferous age. If this conclusion be correct, the cis-Himalayan strata of Simla are probably, in part at least, altered palæozoic marine beds; although the absence of fossils, and the great petrological differences from the trans-Himalayan formations, have led to the suggestion, that the Blaini and Król rocks

belong to the peninsular type. No definite connexion with peninsular rocks can, however, be made out.

There is much obscurity attending the relations of the Blaini and Król rocks of the Lower Himalayas to the older gneiss; and in some places, instead of the slaty series resting upon the gneissic formation, the latter appears to overlie the former. There can be little doubt but that such an appearance is illusory, and due to disturbance of later date; in all probability, the Blaini and Król rocks, although of palæozoic age, are much newer than the gneiss, and they are certainly unconformable to it. There appears some reason for inferring that the palæozoic slates, sandstones, and limestones occupy hollows formed by denudation in the old gneissic rocks, and that subsequent pressure has produced the appearance of inversion. If this be a correct view, it is probable that the cis-Himalayan palæozoic rocks are in great part of freshwater origin, and that the present crystalline axis of the Western Himalayas approximately coincides with the shore of the ancient palæozoic continent, of which the Indian Peninsula formed a portion.

Passing eastward along the Himalayas, the whole of the country north of the snowy range is unknown; and it is only possible to infer, from a few marine fossils brought from various parts of Tibet, that there is a continuation in that direction of the Spiti and Kumaun rocks. Along the southern slopes of the Himalayas also, owing to political difficulties, scarcely anything is known of the geology. A possible representative of the Król group is found near Kathmándu in Nepál, and another may perhaps be traced in Bhútan; but the only formation of definite age in this direction is a peninsular rock, the Damúda, to which it will be necessary to refer presently. To the eastward, in Burma, the only fossiliferous palæozoic rock known is the carboniferous limestone of Tenasserim. Devonian rocks are said to have been found in Eastern Tibet.[1]

In the preceding brief survey of our present acquaintance with the azoic and palæozoic formations, it will be seen that, so far as the rocks are known, there is a remarkable divergence between the peninsular and extra-peninsular rocks: a difference so great as to lead to the conclusion, that very different conditions prevailed in the two areas. To this there may have been at first an exception in the case of Burma, where the oldest rocks have not been shewn to be distinct from those of the Peninsula; although, in the newer palæozoic carboniferous times, the sea evidently covered part of the Burmese area; whilst there is no trace of any marine carboniferous formation in the Indian Peninsula.

[1] Comptes Rendues, LVIII, p. 878:—Geol. Mag., I, 1864, p. 76.

At the same time, there is a well-marked distinction between cis-Himalayan and trans-Himalayan formations; the former differing less from the peninsular type than the latter do, and the latter being marine, whereas the former are, in part at least, freshwater. It will be seen that there is the same, or even a greater, contrast from the extra-peninsular formations shewn by the mesozoic and tertiary rocks of the Peninsula, to which it is now necessary to turn.

Gondwana system.—It has already been pointed out, that, in dealing with Indian rocks, it is impossible always to keep to the classification adopted for very different formations in a distant part of Europe. There is good reason for believing that the lowest Gondwána beds of the Peninsula may be of upper palæozoic age; but they are divided by a great break from the next older series, the Vindhyans, whilst they are intimately connected with the Upper Gondwána rocks, which are certainly mesozoic. In returning from the comparison of the extra-peninsular palæozoic rocks to the peninsular area, and in commencing the examination of the Indian mesozoic formations, it is necessary to commence with formations which may represent, in part at least, the upper palæozoic marine beds of the Punjab, the Himalayas, and Burma.

In the Gondwána system organic remains appear for the first time in the Peninsula. But even in these rocks no marine fossils are found in the lower sub-division, all the groups of which consist of sandstone and shale, in some cases with beds of coal, and appear to be of freshwater origin. From a consideration of all the facts known, the approximate age assigned to the Lower Gondwánas is permian and triassic, possibly a little older or a little newer, the evidence being by no means conclusive: the Upper Gondwánas are with more certainty classed as jurassic. The upper sub-division also consists chiefly of sandstones, occasionally associated with clays or marls; and in one instance the beds are interstratified with contemporaneous basaltic lava flows.

The area occupied by the beds of the Gondwána system, although very extensive, is mainly confined to the country between the Narbada and Sôn to the north and the Krishna to the south; and a very large portion of this region to the westward is occupied by newer beds. The only outliers in the Peninsula beyond the limits named are near the east coast, and to the westward in Kattywar, Cutch, and Jesalmir, and consist of Upper Gondwána beds alone; but Lower Gondwánas have been traced for some distance along the base of the Eastern Himalayas.

The Gondwána beds are distributed in large basins, some of which shew a remarkable coincidence with the existing river valleys; and it has hence been inferred that, as the beds are probably of fluviatile origin,

the river valleys of the present day are the same, or nearly the same, as those of the Gondwána period. This conclusion is, however, not admitted by all observers, and must be received with great caution; the distribution of the rocks, in some instances, being quite different from that of the existing drainage areas, and the agreement between the ancient Gondwána basins and the modern river system being perhaps due, where it exists, to the softness of the Gondwána rocks, and to their having in consequence been more easily worn away by rivers. It is a curious circumstance, that the lowest Gondwána beds are singularly constant in character throughout the whole extensive area in which they are found; whilst the difference between the rocks in the different basins is much greater in the higher members of the Lower Gondwána series, and becomes still more marked in the Upper Gondwánas. There are also more marks of local disturbance, sharp dips and faulting, in the Lower Gondwána rocks than in the upper; and it is clear that in some instances the Lower Gondwánas had been tilted and faulted before the Upper Gondwánas were deposited. It is consequently far from improbable that the present Gondwána basins date from Upper Gondwána, not from Lower Gondwána, times. In the Upper Gondwánas, too, there is evidence that the coast line of the Peninsula had begun to assume its present form; for in many places along the east coast, from near Cuttack to Trichinopoly, small patches of Upper Gondwána rocks are found, in several cases interstratified with marine beds, but yet distinctly, in part, shewn to be either of fluviatile, deltaic, or littoral origin, from the coarseness of the materials and the abundance of remains of land plants. In some places, too, as near Ellore, these Upper Gondwána beds of the east coast rest upon a denuded slope partly of gneissic and partly of Lower Gondwána rocks, having the appearance of a plane of marine denudation. Gondwána beds occur near the east coast farther still to the north, close to Cuttack, but no marine beds are associated; and to the north, and north-east no marine jurassic rocks are known to exist. There is consequently no evidence whether the jurassic coast ran farther north in that direction; although, as will be seen, the sea extended much farther in that direction in cretaceous times. Again, to the westward, in Cutch, Upper Gondwána beds are found interstratified with marine rocks of upper jurassic age, and containing the same fossils as the beds on the east coast; the same Upper Gondwána rocks have been traced in Kattywar, and some, probably a little older, occur in the great desert near Jesalmir and Bálmir, where also marine jurassic beds are associated. Now, it is a remarkable fact, that this indication of the ancient coast line is entirely confined to the Upper Gondwána beds; Lower Gond-

wánas being only associated with the upper in a single instance, near Ellore, where the two are quite unconformable, and where the lower series appears to have been planed away, before the deposition of the upper, by the marine denudation to which the slope already mentioned is due. It is only reasonable to conclude, that important changes in the configuration of the country took place in the interval between the Upper and Lower Gondwána periods.

The most marked distinction between the Gondwána basins and the existing river drainage areas is found in the Sátpura region, where the Gondwána rocks form the watershed between the Narbada and Godávari, and do not descend into the main valley of either river; the Gondwána basin of the Godávari itself being quite distinct. In this instance, however, if there had been any coincidence in the former and present river areas, the resemblance could only be due to accident, or to the facilities afforded by the soft Gondwána formations for subaërial denudation, because the whole region in later mesozoic and early tertiary times was covered with a uniform sheet of basaltic lava flows, by which all the ancient features of the country must have been obliterated. It is out of this great sheet of igneous rock that the hills and valleys of Western and Central India have been carved in tertiary and recent times; and amongst the tracts thus exposed by denudation are the Gondwána regions of the Sátpura hills, and, in great part, of the Sôn, Upper Mahánadi and Godávari valleys. Indeed, the vast tracts of Gondwána rocks now exposed in these areas owe their preservation, in all probability, to the protection from denudation afforded by the overlying traps.

In part of Bengal a change in the configuration of the country through the eruption of igneous rocks took place at even an earlier period,—in the Upper Gondwána epoch itself. In the Rájmahál hills, resting unconformably upon the lower Gondwána Damúdas, themselves by no means the uppermost members of the lower sub-division, there is found a band of Upper Gondwána sandstone; and over this again, with slight local unconformity, a great thickness of basaltic lava flows, with interstratified sedimentary beds containing plants. It is not probable that these lava flows were restricted to their present area; and, from the abundance of trap dykes in those Gondwána basins of the Damúda valley which are in the neighbourhood of the Rájmahál hills, and the gradual diminution in the size and number of such dykes as the distance from the hills increases, it is highly probable that part of the Damúda valley was at one time also covered by horizontal traps. Whether this was the case or not, depends upon whether the highest Gondwána beds, referred to the Mahádevas, in the Damúda valley, are older than the

Rájmahál lava flows or newer. If the former, the ground may have been covered with basalt; if the latter, this can scarcely have been the case, as a layer of basalt would have been preserved below the Mahádeva outliers. In favour of the newer age of the Mahádevas, it should be noted, that no trap dyke has been found in them; although such intrusions occur in all Lower Gondwána beds.

So great an outburst of igneous rocks was probably preceded and accompanied by very important changes in the elevation of the neighbouring country; and it is evident that all these changes, and the alteration of the surface by the outburst of traps, must have produced great modifications in the form of the river valleys. Indeed, the manner in which a number of small Lower Gondwána basins, now isolated, but shewing, by the disturbance they have undergone, that their present isolation is due to denudation, are scattered over the country to the west of the Rájmahál hills, indicates the probability that all were once parts of an extensive river valley; and the complete absence of Upper Gondwána rocks in all these small basins may very possibly be due to the breaking up of the river valley in the interim between the Lower and Upper Gondwána periods.

On the eastern side of the Rájmahál hills there is also a possibility that the traps extended across the area now occupied by the upper part of the Ganges delta, and were connected with the stratified traps found north of Sylhet. This is no more than a suggestion; but still the Lower Gondwána land, in all probability, extended to the north-east, as is shewn by the occurrence of Damúda rocks north of Assam; and it is quite possible that the Upper Gondwána terrestrial area may have been continued in the same direction. At the same time, the Sylhet traps may, even if contemporaneous with those of Rájmahál, belong to a different volcanic centre. But the Rájmahál traps shew no signs of thinning out to the eastward, where they disappear beneath the alluvial deposits of the Ganges valley; and it is only reasonable to suppose that they extend for a considerable distance beneath the alluvial covering. Thus, even in Upper Gondwána times, not only is there no reason for supposing that the greatest river valley of India existed, but there is some indication that it had not been formed. As will be shewn presently, there is a probability that the depression of the Gangetic plain, to the eastward at all events, is of tertiary origin.

The very marked difference between the Upper and Lower Gondwána floras, and the connexion that exists between the plants found in the different groups of each of the two major sub-divisions of the system, also point to a break of time of considerable magnitude between the two series.

Physical geography of Gondwana period.—We can thus form some slight conception of the physical geography of India in the Upper Gondwána period. The sea then, as now, occupied the Bay of Bengal, and a portion, at all events, of the Arabian Sea; and large rivers traversed the land then, as now, though not in precisely the same courses. The general form of the southern part of the Peninsula may have agreed more nearly with the present contour than the northern; for the sea occupied the Indian desert and portions of the Punjab and Himalayas. There is not the same clue to the form of the land in the Lower Gondwána period; and all that can be said with certainty is, that the northern part of the Peninsula was a terrestrial area, traversed by great rivers. To the north-east the occurrence of Damúda beds at the base of the Himalayas, in Sikkim and Bhután, may intimate an extension of land in that direction, and a possible connexion with the Chinese area, in which plants allied to those of the Damúda are known to have been found. Such faint indications of the relations between the Damúdas and other Himalayan beds as can be learned from the very obscure mode in which the Gondwána rocks occur in the Eastern Himalayas will be found in Chapter XXV. All the data hitherto ascertained are too imperfect for any conclusions as to age to be based upon them.

Two other subjects of interest remain for notice: the connection with other countries shewn by the fossil flora and fauna of the Gondwána period; and the evidence of climate.

Relations of Gondwana flora and fauna.—The plants of the Lower Gondwánas consist of acrogens and gymnogens; the former, represented by *Equisetaceæ* and ferns, being far more abundant both in species and individuals than the latter, consisting of cycads and conifers. In the Upper Gondwánas the same classes are found; but the proportion is reversed, the conifers, and especially the cycads, being more numerous than the ferns, whilst *Equisetaceæ* are barely represented. The fauna is singularly poor, no animal remains being found in most of the beds; and even plants are scarce in many of the groups. The only formations in which plant remains occur in abundance are the Karharbári, Damúda, and Rájmahál; and even in these the number of species is comparatively far from great.

There are three distinct floras in the Lower Gondwána series: (1) the Tálchir and Karharbári, (2) the Damúda, and (3) the Panchet; and two, besides some intermediate groups, in the Upper Gondwánas: (1) the Rájmahál, and (2) the Jabalpur and Cutch flora. The Tálchir and Karharbári flora has a marked affinity to that of the European Trias, and especially to the Bunter, the lowest sub-division of the Trias; but there is an equally

close connexion with the upper palæozoic (carboniferous) flora in Australia. This resemblance to the Australian carboniferous flora is very much more marked in the next Gondwána group, the Damúda, a considerable proportion of the forms being closely allied, and some being identical; and there is also a close connexion between the Damúda plants and those found in the Karoo series of Southern Africa. Some of the same plants are also found in China; but the details are as yet imperfectly known. On the other hand, the affinity between the Damúda flora and that of any lower mesozoic or palæozoic group in Europe is comparatively small. Some Damuda plants are certainly allied to species found in carboniferous, permian, triassic, and jurassic beds, and perhaps the most marked connexion is with the lower oolites; indeed, the resemblance of a few plants in this case led to both the Damúda beds and the Australian being for a long time classed as jurassic. As will be seen presently, however, there is a very much closer alliance between the plants of the lower oolites and those of the uppermost Gondwána flora; and the latter is divided by an immense thickness of beds and several successive floras from the Damúdas.

Only vestiges of animal remains have been found in the Karharbári and in the typical Damúda beds; but in the Mángli beds, belonging in all probability to the Upper Damúdas, a labyrinthodont skull has been obtained, closely related to a type found, like some Damúda plants, in the South African Karoo beds. In the Panchet group, above the Damúdas, remains of dicynodont reptiles occur, also evincing a connexion with the same South African beds. Two labyrinthodonts, also found in the Panchet beds, are most nearly allied to European triassic forms. Of the four species of Panchet plants known, two are European rhætic species, and the others are allied to rhætic forms, one being, however, nearer to a lower triassic type.

Of the Upper Gondwána floras, the Rájmahál has but little in common with any European assemblage of plants; but it, like the Panchet, is most nearly affined to the rhætic. As between the Rájmahál and Panchets there is the greatest break, both in palæontology and geological sequence, in the whole Gondwána system, the circumstance, that the flora of both is related to that of the same minor sub-division of the European series, shews that too much weight must not be attached to similar cases of affinity in determining age. The Cutch and Jabalpur flora again contains several plants, apparently identical with forms found in lower oolitic (middle jurassic) beds in Europe, the relations, as already stated, being by far the most intimate of any between Gondwána and European fossil floras; but the Cutch beds overlie uppermost jurassic

marine strata, and underlie upper neocomian beds, so that if marine fossils be accepted as a criterion of age, the horizon of these Cutch strata with lower oolitic plants must be very nearly that of the European Wealden. In one of the Upper Gondwána groups, that of Kota-Maleri, found in the Southern Central Provinces, and supposed, on the evidence of a very poor flora, to be intermediate in age between Rájmahál and Jabalpur, a considerable number of ganoid fishes, with distinctly liassic affinities, belonging to the genera *Lepidotus, Tetragonolepis*, and *Dapedius*, are found in a bed interstratified with rocks containing teeth of *Ceratodus*, and remains of two reptiles, *Hyperodapedon* and *Parasuchus*—all characteristic triassic forms. The contradictions as to age of the Gondwána fauna and flora are thus very great, so long as these beds are compared with the European sequence. As a general rule, in the Upper Gondwánas all the forms appear to have lived at a later period than in Europe; but in the Lower Gondwánas the reverse is the case. The Rájmahál beds are very possibly not quite so old as rhætic. There is much probability that the Kota-Maleri group is newer than liassic, and it is certainly of later age than the trias; the Umia group of Cutch is clearly posterior in date to the lower oolite, whilst, on the other hand, amongst the Lower Gondwána formations, the Karharbáris are probably older than triassic; the Damúdas are certainly of pre-jurassic age, and the Panchets may very possibly, although triassic, represent a somewhat earlier period than that of the rhætic group.

It would of course be equally unsafe to insist upon the affinities of the Karharbári, Damúda, and Rájmahál floras, and of the Mángli and Panchet faunas, with those of various beds in South Africa and Australia, as proving contemporaneous age. But the very marked affinities between the different terrestrial forms of plants and animals in the rocks of these distant regions may be fairly assumed to shew that there was at times, if not continuously, land connexion between the two countries. In the Lower Gondwánas the relations with the Australian forms of life are stronger than with the European. Whilst the Damúda flora exhibits the most marked relationship to that found in beds intercalated with marine carboniferous rocks, or conformably overlying them, in Australia, neither the Australian nor the Damúda plants have any resemblance to those found in the coal-measures of Europe; although the latter occur in beds having precisely the same relations to the carboniferous mountain limestone as the Australian rocks have to the marine beds with mountain limestone fossils. It is reasonable to infer that at this period, or soon after, India was united with Australia by land, but not with Europe, and that the latter connexion took place later. Hence the occurrence of such Lower Gondwána types as are found in European beds in rocks of

later date in the last-named area: for instance, the genus *Phyllotheca*, found in the carboniferous beds of Australia and the Damúdas of India, but not in any formation older than jurassic in Europe. It is not improbable that the Lower Gondwánas of India are of intermediate age between the carboniferous of Australia and the trias of Europe.

Above the Lower Gondwánas the evidence of connexion with Australia is faint; and where any exists, it is perhaps, on the whole, in favour of a passage from India towards Australia. Thus the genus *Ceratodus* of the Indian Upper Gondwánas is represented by living freshwater fishes in Australia; and *Hyperodapedon* is most nearly related among recent lacertians to the New Zealand *Hatteria*. Such affinities, however, are of minor moment. In the case of Africa, the land connexion appears to have been more permanent, and it may have existed continuously to tertiary times. Some evidence on this point will be mentioned hereafter.

Some of the plants common to the Cutch or Jabalpur beds and the lower oolitic or middle jurassic rocks of Europe have also been found in parts of Eastern Europe and Western and Northern Asia; so that there is abundant evidence of this flora having been widely diffused in the northern hemisphere. Unfortunately the age of the rocks containing the plants appears in the majority of cases to have been inferred from the flora; and as this has been shewn to be insufficient evidence in India, it is impossible to tell whether the rocks at the various localities in South-Eastern Russia, the Caucasus, Northern Persia, Siberia, Northern China, and Japan, at which plants resembling those of the lower oolites have been found, are of contemporaneous origin; or whether they are intermediate in age between the middle jurassic beds of Western Europe and the upper jurassics or Wealden of Western India. It is fair to infer that the countries were connected by land during a portion of the intervening period; but it is quite uncertain how far the union was permanent, or to tell whether it still existed in upper jurassic times. It appears probable that the sea extended to the westward far north of Cutch; but there are some remarkable differences between the jurassic rocks of Cutch and those of the Himalayas; and these differences may have been due to a land barrier between the two regions.

Climate of Gondwana epoch.—The climatological evidence contained in the Gondwána rocks is very curious; and although it cannot be said to prove an epoch of low temperature, it certainly suggests it. In the Tálchir formation, almost wherever that extensively developed group is exposed, fragments of metamorphic, transition, or Vindhyan rocks are found imbedded. These fragments are always rounded, often of large size (many having been measured 6 feet in diameter, and some are pro-

bably larger), and in many cases imbedded in the finest silt. It is difficult to understand how such large blocks can have been transported and deposited in a fine mud without the agency of ice: roots of trees are out of the question where the occurrence is on so large a scale. In one instance, moreover, some of the blocks were found to be polished and striated, and the underlying Vindhyan rocks were similarly marked. The appearances are not such as would be produced by glaciers; and it appears more probable that if ice transported the blocks, it was in the fluviatile form known as ground ice. It was at first suggested that this might be the case without any change in the temperature, as the Talchir formation might have been deposited on a plateau sufficiently lofty for ground ice to be formed. But the additional evidence since obtained of similar deposits, apparently of glacial origin, in South Africa, in beds precisely corresponding to the Talchirs in position, the likelihood that the Permian breccias of England are also glacial, the poverty of the Permian fauna, and the great break in forms of life at the close of the palæozoic period, together with the additional astronomical data in favour of variation in the sun's heat—all combine to suggest the possibility of recurrent epochs of diminished temperature having taken place at intervals in the earth's history, and of one of these intervals having coincided with the Permian epoch. This might perhaps also explain the migration of Australian and African plants to the tropics, and the subsequent dissemination of these same plants in the temperate regions of Europe and Asia, as the earth's temperature increased again. There is nothing in the Lower Gòndwána flora to indicate tropical affinities: the flora, as already noted, is poor, and the ferns might as well have inhabited a damp-temperate climate as a tropical one; whilst the beds containing the Talchir boulders are singularly devoid of life, either vegetable or animal.

It should here be noticed that two cases of large boulders imbedded in a fine matrix are known in India amongst earlier rocks, and one at least in a later formation. One of these was in some transition beds, of unknown relations,[1] resting upon Maláni volcanic rocks near Pokran, between Jodhpur and Jesalmir, in Rájputána. Here also a striation of the underlying formation was observed. The second case is in the Himalayas of Pángi, south-east of Kashmir. Here the old slates, supposed to be silurian, contain boulders in great numbers. The third instance was in the Salt Range, where blocks of great size are imbedded in a clay supposed to be of upper cretaceous age; and one of the boulders was found to be polished and striated in a very characteristic manner on three different faces.

[1] Rec. G. S. I., X, p. 13. The notice of this boulder bed has been omitted in Chapter II of this work.

Another method of accounting for the difference of temperature in past times is that noticed a few pages back, when the absence of life in the Vindhyan rocks was mentioned—a possible change in the direction of the earth's axis. Whether such a change can have taken place is a question that may be left to astronomers and mathematicians, and that appears as yet to be by no means decided. So far as the climate of India in past times is concerned, granting, as appears probable, that a lower temperature prevailed in certain past epochs, either a secular refrigeration or a change in the earth's axis would equally account for the deficiency of heat. It is extremely doubtful, however, whether any change in the relative positions of the earth's surface could satisfactorily account for the recent glacial epoch, of which, as will be seen, the effects were probably felt in India; and if a cool temperature prevailed in the Permian period, it is highly probable that it was due to the same cause as in pleistocene times.

Jurassic marine rocks.—The marine zones associated with the Upper Gondwána beds of the east coast have not, with one exception, been accurately determined; but few characteristic forms of fossils occur, and the majority of the species found have not been determined. The exception is the highest marine bed known, in which forms of *Trigonia*, *T. ventricosa*, and *T. smeei*, have been found, characteristic of the higher or Umia beds in Cutch. The Cutch jurassics afford a very complete representation of all the European jurassic beds above the inferior oolite; the Bath, Kelloway, Oxford, Kimmeridge, and Portland faunas being more or less clearly distinguished. No equally full sequence of marine jurassic beds is known to the northward in the extra-peninsular area, but the upper jurassics are, as will presently be shewn, represented in the Punjab and the Himalayas. North of Cutch also, in several parts of the desert country between the Indus and the Arvali mountains, jurassic rocks are found, the best known being, perhaps, some near Jesalmir, of Oxford or Kelloway age: with these, as already mentioned, are associated beds apparently of freshwater or littoral origin, and containing obscure remains of terrestrial plants and fossil wood. It is probable that the jurassic coast line of the Peninsula ran northward from Cutch through Western Rájputána to the Salt Range of the Punjab, where also marine jurassic rocks containing plant remains are found, but are restricted, like carboniferous and triassic marine formations, to the western part of the range.

The highest jurassic group in Cutch, that of Umia, contains at the base a marine fauna, with several species of mollusca common to the Portland zone of the European oolites, and also some forms, amongst

which two *Trigoniæ*, *T. ventricosa* and *T. vau*, are conspicuous, characteristic of certain very high jurassic beds in Southern Africa. The plants identical with forms found in the inferior oolite beds of Europe occur at a rather higher horizon; but there is some intercalation of marine fossils above the plant beds. Above the whole, whether conformably or not is uncertain, is a thin band with upper neocomian *Cephalopoda*; and this is succeeded by Deccan trap, the last-named formation being unconformable to the underlying beds.

Cretaceous marine beds.—No association of upper cretaceous beds with the marine jurassic rocks has hitherto been clearly traced on the eastern shores of the Peninsula; although some fossils, which may belong to a very high cretaceous horizon, occur at the base of the traps near Rájámahendri (Rajamundry) and Ellore, overlying beds, believed to be identical with those containing *Trigonia smeei* and *T. ventricosa* a little farther to the north-east; and some cretaceous mollusca have been brought from Sripermatur, west of Madras, where, however, the relations of the rocks containing them to the beds with marine remains in the Sripermatur Upper Gondwána beds are very obscure. By far the most important cretaceous deposits of India are those of the neighbourhood of Pondicherry and Trichinopoly, where a series of marine fossiliferous strata, classed in ascending order as the Utatúr, Trichinopoly, and Arialúr groups, correspond in age to the European cretaceous beds, from Upper Greensand or Cenomanian to Upper Chalk or Senonian inclusive. The uppermost strata of the Arialúr group may possibly represent a still higher horizon; but they have not been definitely distinguished. The lowest group or Utatúr rests in places, with slight unconformity, on Upper Gondwána beds, apparently, to judge by the flora, of an age intermediate between Rájmahál and Jabalpur, and elsewhere upon the gneiss: at the base of the Utatúr group there is frequently a great coral reef. Great unconformity exists between the Utatúr and Trichinopoly groups, and some may also occur between the Trichinopoly and Arialúr; but it is chiefly shewn in the latter case by overlap.

All the groups are in part or wholly of littoral origin; none appear to be deep-water deposits. Fossil wood is found abundantly in the two higher groups; and there is evidence of a tract of land north of Trichinopoly having been elevated above the sea and brought under the influence of denudation in the interval between the Utatúr and Trichinopoly groups. Everything combines to suggest that the eastern coast line of Southern India in upper cretaceous times was but a few miles farther west than it is now, and that the general direction was the same. The occurrence of marine beds at the base of the traps near

Rájámahendri and Ellore, although the geological horizon is not quite certain, and may be later than that of the Arialúr beds, tends to indicate the continuance of the same coast line. Again, in the Khási and Gáro hills, and throughout a great part of the Assam range, marine cretaceous beds occur, containing in large numbers the same fossils as the rocks of Trichinopoly, and probably deposited in the same sea, and very possibly on the same line of coast. There is, however, a break between Ellore and the Gáro hills; and there is not the slightest indication of marine conditions in cretaceous times in the Ganges valley. Marine cretaceous beds occur also in Burma; but only one fossil, an ammonite (a Trichinopoly species) has hitherto been procured from them.

Similar fossils are not found elsewhere in India; but in South Africa there is again, as in the Gondwána and marine jurassic beds, a singularly close connexion with the rocks of Southern India. In some marine cretaceous strata of Natal, the majority of the fossils found are identical with those of the Trichinopoly formations. As the fossils are chiefly shallow-water and littoral forms, it appears a probable conclusion, that a line of coast extended in cretaceous times from India to South Africa.

Distribution of cretaceous land.—From the remains found in another part of India, some farther indication is afforded of the distribution of land in the upper cretaceous period. In the Narbada valley here and there, from Barwaha (Barwai) to the neighbourhood of Baroda, some poorly fossiliferous sandstones and limestones are found at the base of the Deccan traps; and near Bágh, a band containing a rather better series of fossils has been discovered in a bed associated with these sandstones. The fossils are characteristically of Upper Greensand (Cenomanian) age, the same as the Utatúr group; but only one species out of eight or nine well-identified forms from the Bágh beds is common to the rocks of Southern India, and this species, *Pecten* (*Vola*) *quinquecostata*, is one of the most widely spread of cretaceous fossils, and is represented by distinct varieties in the Narbada valley and near Trichinopoly. But whilst there is thus a wide difference between the fossils of the Bágh beds and those of the probably contemporaneous strata in Southern India, there is precisely the same resemblance between the Bágh fauna and that of certain beds of the European Upper Greensand, as there is between the South Indian cretaceous deposits and those of South Africa: the Bágh fauna being also found represented in Southern Arabia. It has already been shewn that a coast line probably extended from India to Southern Africa, and it does not appear an unreasonable inference that this coast may have been the southern shore of a land barrier separating the seas

of Europe, Arabia, and Western India from those in which the deposits of the Assam hills, Trichinopoly, and Natal were accumulated. There was thus very probably in cretaceous times the same union with Africa as already indicated in the later palæozoic and older mesozoic period, and the same coast line along the eastern shore of the Indian Peninsula as in the jurassic epoch, but perhaps extending much farther to the north-east. In cretaceous times, as in earlier mesozoic periods, there is no indication of any deposits having taken place in the Ganges valley; and the absence of any mesozoic beds between the tertiaries of the Sub-Himalayas and the ancient rocks of the mountains is rather opposed to any large accumulation of strata, either subaërial or aqueous, having been formed, in the intervening epochs, within the area of the Gangetic plain.

The number of species common to the whole cretaceous fauna of Southern India and that of Europe is 16 per cent.; but the proportion varies in the different groups, being greatest in the Utatúr, 18 per cent., and least in the Arialúr, 12 per cent.; those species only being taken into calculation which are in India peculiar to each group. In the Trichinopoly group the percentage of European species is 15. The gradual diminution in the number of common species may mark the effects of a long-continued period during which the European seas were only in indirect communication, probably by a circuitous route, with those of India; the direct communication having been cut off after the latest jurassic times, when the connexion between the areas was shewn by the same species (*Trigonia ventricosa*, &c.) occurring on both coasts of India. The resemblance of the South Indian to the European cretaceous fauna is greatest in *Cephalopoda*, *Brachiopoda*, and *Echinodermata*, and is much less marked in *Gasteropoda*, *Lamellibranchiata*, *Bryozoa*, and corals. The representation of zones in Europe by the corresponding sub-divisions in India is, however, much less close than in the jurassic rocks of Cutch—a circumstance which also tends to indicate less direct communication between the seas. In the *Cephalopoda*, on which alone the comparison of the Cutch jurassics is founded, this irregularity is especially marked; Neocomian species being found throughout the South Indian upper cretaceous series, and the whole facies of the Utatúr *Cephalopoda*, amongst which no less than 25 per cent. are common to European deposits, agreeing better with the Gault than with the Upper Greensand fauna. The Utatúr group, it should be added, contains no less than 109 out of the 146 species of *Cephalopoda* found in the South Indian cretaceous deposits. Some South Indian cretaceous forms, too, are allied to European jurassic types; and three species belong to a section of *Ammonites* not found in

Europe in higher beds than the trias. Again, amongst the *Gasteropoda*, and especially in the upper or Arialúr group, a large number of tertiary and recent genera are represented.

Deccan traps.—Whilst the upper cretaceous beds were being deposited on the south-eastern coast of India, the volcanic outbursts of the Deccan traps must in all probability have commenced. These rocks form one of the grandest masses of bedded traps to be found in the world, and present several very interesting problems. The Deccan traps consist of a great series of basaltic lava flows, for the most part assuming the form of basalt; all either nearly horizontal, or presenting the appearance of having been so originally. They possess a vertical thickness of between 4,000 and 5,000 feet in some of the Sahyádri scarps, and probably where thickest amount to 6,000 feet at least; and they cover an area roughly estimated at 200,000 square miles, and in all probability originally very much greater. These basalts thin out towards the extremity of the area, but they are traced from Sind to Chutia Nágpúr, and from Belgaum to north of Goona, or throughout 16 degrees of longitude and 9½ of latitude.

The absolute geological date of these igneous eruptions is difficult to fix, and they may have continued to be poured out during a long period. It has been suggested by some geologists that the Rájmahál traps of the Upper Gondwána period and the Deccan traps are portions of one continuous series of outbursts. This is one of those suggestions which are difficult of proof or disproof for want of evidence as to the precise geological horizon of the uppermost traps in the Rájmahál hills; but there is no known connexion between the two series of lava flows. Each is limited to a definite and separate area; for there is no reason to suppose that the Deccan traps ever extended beyond the western part of Chutia Nágpúr, whilst the most western dykes referable to the Rájmahál period are 100 miles farther east. It is not probable that the beds containing the Rájmahál fossil flora can be much newer than middle jurassic, whilst the oldest of the Deccan traps are clearly not older than upper cretaceous; and if the outbursts are supposed to be continuous, it must be inferred that the 2,000 feet of Rájmahál traps represent the accumulations of a period extending from jurassic to upper cretaceous, whilst the whole 6,000 feet or more of Deccan traps were poured out between upper cretaceous and lower eocene times. If the Sylhet traps are really contemporaneous with the Rájmahál, as is by no means improbable, continuity between the Rájmahál and Deccan trap periods is out of the question; for the Sylhet lava flows are overlain unconformably by cretaceous rocks of about the same age (Cenomanian) as those underlying the oldest Deccan

traps; but it is not quite certain that the Sylhet trap is of the same age as the Rájmahál; and even if the two belong to the same period, the uppermost Rájmahál lava flows might be of later date than those in the same relative position in Sylhet.

There is but little petrological distinction between the traps of Rájmahál and those of the Deccan; both consist chiefly of basalts, both are composed of nearly horizontal beds, and both, as will be shewn presently, are of subaërial origin; but in the absence of any direct evidence, it is premature to suggest that there is any connexion between the two formations, or to class them as portions of one great igneous series.

The oldest of the Deccan traps are slightly unconformable to the cretaceous (Cenomanian) rocks of Bágh, whilst middle eocene beds rest with complete unconformity upon the denuded surface of the upper trap beds in Guzerat; and in Sind one thin band of trap, evidently representative of part of the Deccan series, is intercalated between very high cretaceous and very low eocene beds; whilst another band of trap, also apparently of contemporaneous origin, occurs interstratified with upper cretaceous beds several hundred feet below the upper band. The older traps are consequently classed as upper cretaceous; but it is far from improbable that the uppermost beds may be of the earliest eocene age, and that the traps may represent the whole intervening period between cretaceous and tertiary.

The Deccan traps have been very generally considered tertiary, chiefly on the evidence of the freshwater shells in some of the intertrappean beds; but these shells, as will be shewn in subsequent pages, have not been quite correctly determined, and the stratigraphical evidence is intrinsically of more importance, besides being better established.

In the Narbada valley, where the Deccan traps rest upon the marine cretaceous beds of Bágh, there is a peculiarity about the very slight unconformity between the two formations, characteristic of subaërial denudation; and there appears no reasonable doubt that the Bágh beds had been elevated above the sea before they were covered by the lava flows of the Deccan period. Elsewhere at the base of the traps either freshwater beds, known as Lametas, are found, or the basalt rests upon a worn surface, evidently terrestrial, of metamorphic, transition, or Vindhyan rocks. The Lametas are a thin band, closely resembling the Bágh beds in mineral character, and possibly a freshwater representative of them. With the lowest traps of Central India, almost all round the outer limit of the trap area from Cutch through Rájputána and the Central Provinces to the Southern Mahratta Country, freshwater beds, apparently of lacustrine origin, are interstratified; and in these beds numerous freshwater mollusca

and remains of terrestrial plants, with a few insects, small crustacea, and fish, are found. In some few places coarser deposits, evidently transported by rivers, and containing rounded fragments derived from the underlying traps themselves, as well as from older rocks, are met with. All these deposits clearly prove that the lower traps were poured out on a land surface; and amongst the very highest lava flows of Bombay, 6,000 feet or more above the horizon of the Central Indian beds, freshwater deposits are again found, also teeming with life, both vegetable and animal, and affording evidence of terrestrial conditions. There are also found, in many parts of the trap area, thick beds of volcanic breccia, evidently of subaërial formation; for they want the stratified arrangement characteristic of subaqueous deposits. A few laminated ash-beds may have accumulated in lakes.

Despite the fact that the uppermost and lowermost beds are thus demonstrated to be subaërial, that many intermediate layers are also proved not to be of subaqueous origin, and that there is no structural difference between the beds shewn to be subaërial and the remainder of the series, it is still contended by some geologists that the Deccan traps must be submarine. This view was originally advanced before the data now ascertained were known; but the idea has not been entirely abandoned, even since it has been proved that a part at least of the lava flows must have been poured out on a land surface. The great distinction between all such horizontal bedded traps as those of the Deccan and the lava flows of modern volcanoes, and the enormous distance to which the trap flows must have been extended from the point of eruption, are characters not yet explained; but a favourite theory with some geologists, that such flows must have been submarine, because a lava flow would preserve its heat and fluidity longer under the pressure of a large volume of water than in the air, is not only unproved, but is opposed to the known properties of water. Moreover, submarine volcanic rocks are common in the older formations, and are very different in character from such rocks as the Deccan traps. All such subaqueous accumulations are interstratified with ordinary sediment, and so closely intermixed, that it is often difficult to tell whether they are really of igneous origin or not. Such are the trappoid beds of the Indian transition rocks. Now, in no single instance have rocks of this kind been detected in the Deccan trap series; on the other hand, the structure of the beds from top to bottom is that of ordinary subaërial lava flows. It may fairly be concluded that all such bedded traps as those of the Deccan and the Rájmahál hills are of subaërial origin.

Although the Deccan traps occasionally overlie or underlie marine deposits, there is almost always distinct unconformity between the two;

and there are but two localities, in very distant parts of India, where any interstratification of marine beds with igneous rocks has been detected. These cases of interstratification are, however, the sole clue afforded to the outline of the Indian continent in the Deccan trap period. The one has been already noticed as taking place in Sind; the other is at Rájámahendri. In both instances the trap is probably littoral, if not truly subaërial; in Sind, coarse beds, conglomerates, and sandstones are associated with the lower band of trap, whilst immediately over the upper layer, sandstones, apparently of freshwater, and probably of fluviatile origin, are found. Near Rájámahendri the bottom flow of basalt rests upon a marine stratum, and is overlain by a band containing estuarine fossils, followed by a second lava flow. The latter locality may intimate a continuance of the general line of coast that has been shewn to have existed in upper jurassic and cretaceous times, and that remains to the present day.

The Rájámahendri traps may possibly be part of a distinct outburst, as no lava flows are preserved in any portion of the interval, 210 miles in length, between Rájámahendri and the main trap area in the Godávari valley. In all probability, the limit of the trap outliers in Rájputána, the Vindhyan table-land, Chutia Nágpúr, and the Southern Mahratta Country nearly corresponds with the original boundary of the region covered with igneous rocks; for just beyond the limit laterite is found in many places resting directly on the older rocks; and the laterite appears, as will presently be seen, to be of but little later date than the highest traps. But along the Bombay coast the traps disappear beneath the sea, where they are at their greatest development; and, in consequence of their westwardly dip, the rocks seen on the coast are the highest known. How far the igneous rocks of the Deccan period extend in this direction, it is impossible to say, but probably for a considerable distance; for some of the great centres of eruption, to judge by the prevalence of dykes and similar intrusions, were in the neighbourhood of the west coast. It is probable also that the land in the Deccan trap period extended for a long distance to the westward.

Another circumstance, tending to indicate that the approximate limit of the area covered by the traps in India is shewn by the outliers, is, that throughout the circuit of the igneous rocks, from Rájputána, *viâ* Chutia Nágpúr, to the neighbourhood of Belgaum, trap dykes are rare or wanting; whilst in parts of the Narbada valley, in the Konkan north of Bombay, in Guzerat and Cutch, dykes and other intrusions abound. Many of these intrusive masses are of large dimensions, sometimes miles in diameter; and they doubtless fill the channels through which the eruptive rocks reached the surface. It is probable that the Deccan

traps flowed from vents without the formation of volcanic cones, as no traces of the inclined beds of such cones have been found; and the distinction may have been due to the greater fluidity and larger mass of ejected lava, and to its consequently increased power of transporting all the materials brought to the surface by igneous agency to a much greater distance from the point of emission.

High-level laterite.—It is evident that the close of the volcanic outbursts left all the surface of Western India a huge plain of basaltic rock, the plain which later denudation has carved into the hills and valleys of the Peninsula. The only formation superposed upon the basalt throughout the greater part of the area, with the exception of gravels and clays of late tertiary or subrecent date, is the high-level laterite, or iron clay, a ferruginous and argillaceous rock, from 30 or 40 to 200 feet thick, capping the summit of many of the highest trap plateaus, and also occurring on other rocks, beyond the limits of the trap area, in such a manner as to shew that the caps now remaining are merely isolated fragments of a bed once far more extensive. This bed probably covered a large portion of the trap area and the neighbouring regions, and perhaps extended throughout the greater portion of Peninsular India. Nor is this all. In the nummulitic beds of Guzerat, Cutch, Sind, and the Salt Range of the Punjab, and in the Subáthu beds of the Sub-Himalayas, all of middle eocene age, there are found one or more beds of ferruginous rocks absolutely undistinguishable from laterite, and probably, from their wide extent, of contemporaneous origin.

In many places the laterite bed passes into the uppermost traps, and hence it has been very naturally inferred, that laterite is merely an altered form of the basaltic rock itself; but it appears most probable that decomposed basalt, when iron peroxide is added, forms laterite, and that consequently passage from the one into the other is natural; but that the high-level laterite bed is really throughout of detrital origin, as it is proved to be in places by containing pebbles and sand. It probably consists of altered volcanic detritus, perhaps of scoriæ and lapilli; the excess of iron being either due to the ferruginous nature of the volcanic outbursts, or to a process of washing by which the lighter, less ferruginous matters were carried farther away from the original source of the materials, and formed deposits less easily consolidated, and, in consequence, more easily destroyed by denuding agencies. Other laterite formations, deposited after much denudation of the traps had taken place, and found at low levels in various parts of India, may have been derived, in some cases at least, from materials provided by the denudation of the high-level form.

Tertiary coasts of Peninsula.—With the high-level laterite the sequence of older rocks in the peninsular area of India may be considered to close, late tertiary and recent deposits alone remaining, except in a few places on the coast. It will now be necessary to return to the extra-peninsular areas, and to see what was their history in mesozoic and early tertiary times, so far as a record is preserved by the rocks, whilst the Peninsula, as has been shewn, was a land area, as it is now. It should be first stated that the tertiary rocks around the coasts of the Peninsula afford but a faint indication of the distribution of land and sea in tertiary times. No marine beds of later date than cretaceous are known on the east coast, and the only tertiary beds are the Cuddalore sandstones of uncertain date and origin; whilst on the west coast the sea certainly covered a portion of Guzerat in eocene and miocene times, the coast lines being perhaps not very different from what they are now, although the sea extended some distance in what is now an inland direction. To the south, in Travancore, for the first time in geological history, we find that a marine deposit was formed in the miocene age; and we may perhaps infer that the southern portion of the western coast then first assumed something resembling its present outline. When treating the probable inferences to be drawn from the Indian fauna as to the former connexion between India and other countries, it will be seen that India may have been directly connected with Africa till the middle of the tertiary period.

Extra-peninsular mesozoic rocks.—The mesozoic history of the extra-peninsular tracts is even more meagre than is that of the peninsular area. Of triassic rocks no trace is known in Sind, none of the formations of that province being of older date than cretaceous; but it is highly probable that triassic strata may exist near Kelát in Baluchistan, as *Ceratites* and *Orthoceratites* have been obtained there. Ceratite beds, probably of Bunter or lower triassic date, are found in the western part of the Salt Range of the Punjab, and in some of the ranges west of the Indus near Isakhel (Esakhel), but have not been clearly shewn to occur elsewhere; although representative beds may possibly be found in the Himalayas. The overlying beds in the Salt Range are poorly fossiliferous. In Hazára, the upper triassic or rhætic beds with *Megalodon* and *Dicerocardium* alone contain distinctive fossils, the underlying strata being destitute of organic remains; whilst the next beds in ascending order, though probably of rhætic age, contain no characteristic forms. In Northern Kashmir, and throughout the mountain region to the south-east as far as Spiti, and probably farther, resting upon the carboniferous rocks, there is a well-developed series of triassic

beds, commencing at the base, where best known and exposed, in Spiti, with a band of limestone, abounding in *Halobia lommeli*, and resting upon carboniferous beds with *Spirifer keilhavii* and *Productus semireticulatus*. Above the *Halobia* band are beds of concretionary limestone with numerous fossils, many of them similar to those of the upper trias (Hallstädt and St. Cassian) in the Alps. These Himalayan rocks are the Liláng series of Stoliczka, and in places exceed 2,000 feet in thickness. They were classed by Stoliczka himself as upper triassic, or Keuper; but other writers are inclined to consider them more probably of middle triassic age. The next formation in ascending order, the Pára limestone, some hundreds of feet thick, contains *Dicerocardium himalayense* and *Megalodon triqueter*, the latter characteristic of the Dachstein limestone in the Austrian Alps; and above the Pára limestone is the Tagling limestone, 2,000 feet thick, and containing in its lower beds fossils characteristic of the Kossen beds, the characteristic rhætic formation or *Avicula contorta* zone of the Alps, and in its uppermost strata several forms typical of the Alpine liassic beds of Hierlatz.

To the eastward, marine triassic rocks have only been detected in Burma, where *Halobia lommeli* has been found. This, however, is a species of almost world-wide distribution, and consequently of but small value as evidence of any exact horizon. It is impossible to found on this isolated occurrence any conclusions as to the triassic seas of the Burmese area being connected or unconnected with those of the North-West Himalayas.

The triassic and rhætic beds of Western Tibet and the North-West Himalayas are found represented as far north as the Mustágh Range; and the upper triassic beds are widely developed to the northward of the Kuenlun, in the mountains to the north and west of Eastern Turkestan.

A remarkable peculiarity in the triassic fauna of the North-West Himalayas, or rather of Western Tibet (for the area of Spiti, Zánskár, &c., is trans-Himalayan, and inhabited by Tibetans), is the similarity of the fauna throughout the whole series to that of the corresponding beds in the Alps. It is true that the sub-divisions of the strata do not always precisely correspond; but the community of specific forms is such as to render it highly probable that the seas of the two areas must have been united throughout the period. But, at the same time, some land connexion between India and Europe is indicated by the appearance of Karharbári plants in the European lower triassic, and of Panchet species in the rhætic. It is difficult to say whether the trias of the Salt Range was deposited in a different sea from that of Hazára, Káshmir, and Spiti; but the fossiliferous Salt Range beds appear to be older, and the absence of any lower triassic strata between the *Halobia* limestone and the

carboniferous Kuling series, together with the non-appearance of the characteristic upper triassic and rhætic fossils in the Salt Range, although some of them are found in Hazára, and perhaps farther to the westward, may indicate a distinction between the marine areas.

Except in the upper beds of the Tagling limestone, no representatives of the true liassic fauna are known to occur in the neighbourhood of India. The extra-peninsular jurassic formations, although more extensively developed than the triassic, are only known with certainty to exist in the Western Himalayan and Tibetan area and in the Punjab. Jurassic *Cephalopoda*, as well as triassic and cretaceous forms, are said to have been brought from Kelát. The jurassic rocks of the Salt Range have already been noticed in connexion with the closely allied and better developed series in Cutch; and it was shewn how the oolitic formations of the two areas were connected by outcrops in the deserts of Western Rájputána, and were doubtless deposited in parts of the same sea. The upper jurassic rocks of Hazára are more closely connected with those of Spiti.

Above the rhætic and liassic Tagling limestone in Spiti, some slaty beds, with fragments of *Belemnites*, a *Posidonomya*, and other ill-marked fossil forms, occur, and then black, friable shales, with calcareous concretions. These, the Spiti shales of Stoliczka's classification, are generally 200 to 300, rarely 500, feet in thickness, and abound in fossils, especially *Ammonites*. The fauna was classed as middle jurassic (lower to middle oolitic) by Stoliczka; but his views have since been questioned, and it now appears more probable that most of the fossils are upper jurassic (Kimmeridge and Portland); though it yet remains to be seen whether distinct zones can be traced. If they can, some may be older. Above the Spiti shales, the Gieumal sandstone, 200 to 600 feet thick, is found, and consists chiefly of a pale-coloured grit, poor in fossils. The few mollusca that occur are mostly ill-preserved and uncharacteristic bivalves.

To the eastward the jurassic rocks are traced for some distance, being found in Ngári-Khorsum, and probably much farther in Tibet; and it is said that *Ammonites* of the same species as those of Spiti are brought from the neighbourhood of Lhassa. North of the Indus, however, and in Northern Kashmir, jurassic beds do not occur. In the Northern Punjab, representatives of both the Spiti shales and the Gieumal sandstone, possessing the same mineral characters as in Spiti, reappear in Hazára, and are traced to the westward, where, however, they lose their distinctive mineral characters.

Although the fauna of the Spiti shales is believed to indicate the same upper jurassic age as that of the Katrol and Umia beds of Cutch, there is but little resemblance in the fauna. Only five species of Hima-

layan jurassic *Cephalopoda* are recognised by Dr. Waagen as identical with those of the Cutch beds; and even of these, one is a species found only in a lower sub-division in Cutch. Whilst numerous Central and Western European forms are found in the Cutch beds, only one such species is known from the Spiti shales, several, at first referred to European species, having since been considered distinct. On the other hand, there is some similarity of facies between the Spiti shales fauna and that of the Russian oolite. The Spiti jurassics occupy an elliptical tract, extending to the west-north-west as far as Zánskár; but doubtless owing its present restricted area in great part to denudation, as outliers occur to the eastward.

The characteristic *Trigoniæ* of the Umia beds of Cutch are found in beds representative of the Gieumal sandstone in Southern Hazára. It may be remembered that these same *Trigoniæ* are also found in the uppermost jurassic beds on the east coast of the Indian Peninsula, where the few marine fossils occurring in the jurassic Upper Gondwána beds at a lower horizon appear different from those of Cutch. This wide dispersal of a similar fauna at the close of the jurassic period may indicate depression of land and a free communication between the seas, in which the marine beds of the east and west peninsular coasts, the Punjab and Spiti, were deposited. It is possible that about this time the direct land communication with Africa was broken up into islands; though, as has already been shewn, the connexion was probably re-established in cretaceous times.

The cretaceous rocks of the extra-peninsular regions to the east and south-east, in Assam and Burma, have already been noticed: those to the west and north-west are too few and scattered to furnish much information. Doubtless, the greater portion of the cretaceous marine deposits are concealed beneath tertiary formations. Neocomian beds have been found in the western continuation of the Salt Range, beyond the Indus; upper neocomian or Aptian, as already noticed, in Cutch; gault in Hazára, and some beds of uncertain age near Kohát. Upper cretaceous beds, in the form of hippuritic limestone, occupy an enormous area in Persia, and were very possibly originally continuous with similar rocks in Southern Europe. It is not known how far this formation extends in the direction of India. Cretaceous rocks are well developed around Kelát and in some other parts of Baluchistan, and in all probability occupy a large area just west of the British frontier; but no details have been ascertained as to the sub-divisions represented. Away to the northward in Spiti, and again still farther north beyond Chángchenmo, on the frontier of Khoten, beds containing hippurites have been detected,

those in Spiti being the Chikkim beds of Stoliczka; and in Lower Sind at one locality a hippurite has been found in a limestone, the lowest bed exposed; but the Himalayan beds are merely fragmentary outliers, left on the top of hills, and the Sind exposure is a small inlier, seen in one spot only. Above the limestone in the last-named locality are the coarse sandstones, in which, as already mentioned, a flow of Deccan trap is intercalated; and to the sandstones succeed some soft olive-coloured shales and sandstones containing *Cardita beaumonti* and other fossils, and capped by the highest trap-flow. These sandstones and olive shales are of a very high cretaceous horizon, and are doubtless littoral beds. Similar strata are found in the Salt Range of the Punjab; but in a section examined to the west of the Sind frontier both the olive beds and the trap were wanting. It is very probable that the eastern shore of the upper cretaceous sea passed from Sind to the Salt Range and then northward; but the data are very imperfect. Far away to the north-east in Tibet, and to the west of Lhassa, a species of *Glauconia* (or *Omphalia*) has been found, which may indicate the existence of upper cretaceous beds, probably littoral or estuarine.

Tertiary rocks.—The eocene rocks afford a far better conception of the physical geology of North-Western India. By far the most important, and, so far as is known, the most complete, series of tertiary formations yet examined is found in Sind, where, above the upper flow of Deccan trap, sandstones, above 2,000 feet thick, probably of freshwater origin, are found, passing up into the marine Ranikot beds, with a lower eocene fauna. To these succeed the nummulitic limestone or Khirthar group, 500 to 3,000 feet thick; a distinctly marine formation in general, but passing locally into a mass of sandstones and shales having a littoral aspect. The uppermost bands of limestone contain a different fauna; the *Foraminifera* especially being distinct from those of the Khirthar group, and including but two species of *Nummulites*, one, *N. garansensis*, found only in upper eocene and lower miocene beds in Europe, and a second, *N. sublævigata*, peculiar to India. With these upper limestones, sandstones and shales are intercalated; the marine beds soon die out, and a great thickness of sandstones without marine fossils, and probably of freshwater origin, succeeds. The whole of these beds, from the limestones with *Nummulites garansensis* upwards, including 4,000 to 6,000 feet of strata, are classed as the Nari group, and believed to represent the upper eocene and lower miocene of Europe. The Gáj group, 1,000 to 1,500 feet thick, comes next, chiefly composed of marine beds, with an upper miocene fauna; the uppermost layers, however, containing estuarine shells, and passing into freshwater, probably fluviatile, clays

and sandstones, with mammalian bones. These last beds form the lower Manchhars, and are believed to represent the Lower Siwaliks, or Náhans, of the Sub-Himalayan area. The whole Manchhar group comprises in places 10,000 feet of beds, chiefly sandstones and clays, capped by coarse conglomerates, and is considered equivalent to the uppermost miocene and pliocene of Europe. With the exception of occasional estuarine beds near the base, the Manchhar group appears entirely of freshwater origin.

The miocene Gáj beds are not traced north of Sind; in the Punjab the only marine tertiary formations known are of eocene age.

The eocene beds in the Salt Range of the Punjab appear closely to resemble those of Sind, except that the Nari group has not been detected in the former locality: in both cases sandstones and alum clays with lignite underlie the nummulitic limestone. The lowest eocene marine beds in the Salt Range, however, are beneath the lignite and alum group; whereas in Sind the Raniket marine beds overlie a precisely similar formation; and consequently some eocene fossiliferous bands of the former locality may be older than any Sind tertiary beds—a distinction apparently confirmed by the fauna. Above the nummulitic group in the Salt Range there is a break in the sequence, neither Nari nor Gáj beds being known; and it is even doubtful whether the lowest members of the Manchhar or Siwalik group are represented. To the westward, in Kohát, the limestone is thinner, and marls, clays, and sandstones are intercalated; the underlying lignite and alum clay group appears to be wanting, or replaced by red clays, resting upon gypsum and a bed of rock-salt, 300 to 700 feet thick, and probably even thicker in places. Above the nummulitic limestones are upper tertiary sandstones and clays of freshwater origin, as in the Salt Range. In the Eastern Punjab, along the base of the Himalayas, the tertiary rocks consist of two series, unconformable to each other in the Simla area, but undistinguishable by any break farther to the north-west: the lower or Sirmúr beds, comprising three groups, known in ascending order as Subáthu, Dagshai, and Kasauli; and the upper or Siwalik series, composed of lower Siwalik or Náhan beds, middle and upper Siwaliks. Marine beds are confined to the lowest or Subáthu group, which corresponds to the Khirthar group of Sind. Lastly, in the extreme north of the Punjab, the nummulitic limestone of Hazára, Chita Pahár, the Afridi hills, &c., is interstratified with shales, and much contorted and hardened. It is separated from the newer tertiary beds by a line of fault or disturbance. Some bands containing nummulites are found at the base of the overlying rocks, and are evidently of eocene, though perhaps of upper eocene, age; but the whole series above them, consisting of the Murree beds and the Punjab representatives of the

Siwaliks, although attaining an enormous thickness, and occupying a very large extent of country, is destitute of marine bands, and even of well-marked sub-divisions.

The massive nummulitic limestone is probably an open-sea deposit; but, despite its thickness, it varies so much in composition, and passes so often into sandy and shaly beds, as to indicate in many places the vicinity of land. It is well developed throughout the greater portion of Sind, and is found represented in the middle of the Indus valley, near Sukkur (Sakhar) and Rohri, and to the eastward, between Rohri and Jesalmir (Jeysulmere). It extends throughout a great portion of the Sulemán range, and appears, as just shewn, in the Salt Range of the Punjab, and again in the Northern Punjab. To the westward, it is known to stretch through Baluchistan and Persia to the Caucasus and Asia Minor, and thence into Southern Europe. Eastward from the Salt Range, although marine nummulitic beds are found over a considerable area, the interstratification of sandstones and shales, often with terrestrial plants in places, shews the deposits to have been more or less littoral. With the data already given, an attempt may now be made at tracing the Indian coasts of the nummulitic sea.

So far as the eocene beds of Southern Báluchistan are known, they consist of sandstones and shales, and indicate the neighbourhood of land at the period of deposition. This is the case north of Gwádar, and again near Karáchi. The nummulitic limestone thins out greatly, and becomes intercalated with shales and sandstones, in Southern Sind, in Cutch, and in Guzerat. This occurrence of littoral beds along the present coast line may shew that land existed either to the southward, in the area now occupied by the Arabian Sea, or to the north-west. The absence of any eocene marine beds on the coast of the Indian Peninsula, from north of Bombay to the mouth of the Ganges, renders it probable that a considerable expanse of land existed at this epoch; and the land area may very possibly have extended towards Africa, as in cretaceous times, and probably in the miocene period. From the neighbourhood of Surat the nummulitic shore probably extended to the east of Kattywar and Cutch, then possibly, and at a later period certainly, islands, and thence ran through the western portion of the great desert to the Punjab. The sea extended to the north-east as far as Gahrwál, where the most eastern patch of Subáthu beds occurs; but there is no evidence of marine conditions in the Ganges valley between Kumaun and the Gáro hills, south of Assam. The Subáthu nummulitic beds are clearly littoral deposits, and by their aid we may trace the shore line along the south of the Himalayas to the Pir Panjál. The nummulitic limestones of Hazára and

the hills of the Northern Punjab near Attock and Peshâwar are all interstratified with shales; but the formation is of great thickness, and may have been formed in the open sea. That the sea extended northward, is shewn by the existence of nummulitic beds, much altered, in the Upper Indus valley; but they appear to be restricted to the neighbourhood of the river, and it is probable that they were deposited in an arm of the sea, while the surrounding area of Western Tibet was dry land.

It is impossible to say how far eocene rocks can be traced to the north of the Himalayas, in Tibet and Central Asia: some supposed nummulitic beds north of Sikkim have not been sufficiently identified for certainty. Marine eocene beds are found to the south of the Himalayan axis in the Assam range, and thence to the southward, throughout a considerable area, in Burma, west of the Irawadi. Many of the rocks are somewhat altered, and fossils, although found in many places, are often wanting throughout large areas. The marine nummulitic formation has not been observed in Tenasserim; but it is probably continued in the Andamans and Nicobars, and it reappears in Sumatra, Java, and other islands of the Malay Archipelago. Throughout this eastern region freshwater beds with coal are of common occurrence in the eocene rocks; and even in the marine beds coarse sandy deposits frequently indicate deposition near a shore. It is highly probable that the metamorphic area of Eastern Burma was land in the tertiary period, and that the older tertiary deposits of Assam, Burma, and the Malay islands were formed in a deep gulf, or around and amongst an archipelago, like that now existing farther to the south-east. It will hereafter be shewn that some peculiarities of the recent fauna indicate a connexion between the Malay islands, Southern India, and Africa in early tertiary times; and a land area may have extended to the south of India at this period.

Distribution of eocene land.—It will thus be seen that the Peninsula of India in eocene times was part of a tract of land, perhaps of a great continent united to Africa; that there was a sea to the eastward, extending far to the north-east, in the region now occupied by the Assam hills, and another sea to the north-west, covering great part, if not the whole, of Persia, Baluchistan, the Indus plain, and a portion of the Upper Ganges plain. An arm of this sea extended from the north-west up the Upper Indus valley in Ladák. The Himalayas, and perhaps Tibet, wholly or in part, were raised above the sea; but formed in all probability land of moderate elevation. Whether the Himalayan land was united to the Peninsula is, of course, uncertain—but very probably it was; for there is no evidence of marine conditions having existed in the Ganges plain to the east of the Dehra Dún; and if the ferruginous bands of the

Subáthu group be laterite, as they appear to be, the trappean detritus composing them must have been derived, in all probability, from the peninsular area; and the latter must consequently have extended northward, to the base of the Himalayas, in the neighbourhood of Umballa.

It is probable that in the later eocene period of the Nari and Dagshai beds, the sea still flowed as far north as the Punjab; for some Nari *Foraminifera* has been found in that direction: but it is evident that the marine area was diminishing; for the mass of the Nari beds, even in Sind, appear to be of freshwater origin. In miocene times, although marine conditions prevailed throughout Western Sind, the area of the sea was very much smaller than in the eocene period; for all the marine beds of the Punjab and Sub-Himalayas are destitute of marine fossils, and are probably fluviatile deposits.

Later tertiary beds.—East of the Indian Peninsula the area of middle tertiary rocks can be but ill defined for want of information. Marine beds of this age are found in Pegu occupying an extensive area; and if, as appears probable, some marine deposits in the Gáro hills, resting unconformably on the nummulitic limestone, are of miocene age, the difference in extent between the lower and middle tertiary seas in the Bay of Bengal area was probably less than to the westward. All pliocene beds in Assam and Burma appear to be of freshwater origin, with the possible exception of some in the Gáro hills; indeed, after miocene times, the land areas of South-Eastern Asia must have assumed to a great extent their present contour. It has already been pointed out that, for the first time in geological history, the delimitation of the Malabar coast line is indicated in the miocene period.

Some marine beds of late tertiary age, largely developed along the coast of Baluchistan, and hence called the Makrán group, are very probably marine equivalents of the Manchhars and Siwaliks. This would be in favour of the Baluchistan coast line having also assumed its present approximate outline in later tertiary times. The indications of a connexion of land between India and Africa in the tertiary period, as illustrated by the recent fauna, will be discussed in the sequel.

Siwalik fauna.—The mammalian fauna of the later tertiary deposits has received more attention than the fossils of most Indian formations. A most important and interesting assemblage of mammalian remains has been preserved in the middle and upper Siwaliks, the two highest groups of the Sub-Himalayan series. In these beds 84 species of mammals have hitherto been detected, belonging to 45 genera, the whole assemblage having more resemblance to the miocene of Europe than to any later European fauna, but containing a larger proportion of recent genera, and

especially of ruminants, than is found in the miocene elsewhere. Of the associated reptiles, several are recent species; and all the freshwater and land shells found appear to be identical with living forms.

The Náhan beds, forming the lowest group of the Siwalik series, have hitherto proved unfossiliferous; but in the Lower Manchhar beds of Sind, teeth and other remains of a considerable number of species have been found, chiefly of *Ungulata*, comprising, together with several Siwalik species, some genera not known in the Siwalik fauna, and having an older facies. The number of recent genera and of ruminants, in the Manchhar fauna, is very small, whilst several typically miocene genera occur, unknown in the beds of the Siwalik hills. There appears good reason to believe that the Siwaliks and the Manchhars are approximately equivalent, and that the Lower Manchhars probably correspond to the Náhan group. As, however, the Manchhars rest upon the Gáj beds, which are probably upper miocene, it is evident that the Siwalik fauna cannot be older than pliocene. The Siwalik mammalia resemble those of Pikermi in Attica more than any other known fossil fauna; and the Pikermi beds, although they contain a large number of miocene species, and are frequently classed by various writers as miocene, are shewn to be really of pliocene age by containing, at their base, pliocene marine fossils.

Remains of mammalia of Siwalik species have also been found at Perim Island in the Gulf of Cambay, off the coast of Guzerat, and in the later tertiary beds of Burma, which, like the Manchhar beds, overlie miocene marine strata. In both cases the fauna, so far as known, is comparatively poor; but in each instance there is about the same proportion of Siwalik species. There is nothing to indicate that the fauna of the Irawadi beds is older than that of the Siwaliks; and the Perim Island mammalia, although comprising *Dinotherium*, and wanting some of the recent genera found in the Siwalik beds, appear to be of nearly the same age as the latter. It must be inferred, therefore, that in pliocene times there was land communication between the Sub-Himalayan area, Guzerat, and the Irawadi valley.

The valley gravels of the Indian Peninsula, and especially some fossiliferous beds in the Narbada valley, contain a few Siwalik mammalia, associated with species more nearly allied to those now living. Remains of human implements have also been detected in these gravels, which are probably of post-tertiary or pleistocene age.

The marked resemblance between the Siwalik fauna and that of the European miocene may be due to a migration to the southward of the fauna inhabiting Northern Asia and Europe towards the close of the miocene period, when, as is known from other data, the temperature of the northern hemisphere was becoming colder. There is a marked affinity

between the Siwalik fauna and that now found in the Indian Peninsula, an affinity much greater than there is between the Siwalik and Malay fauna; and several genera of Siwalik mammals no longer living in India are found still existing in South Africa. This may be due to the admixture of the fauna inhabiting India in pre-Siwalik times with the Siwalik immigrants; for, as will be shewn, there is a probability that the Ethiopian elements of the Indian and Malay faunas are descendants of earlier immigrants than the pliocene Siwalik types; or (and this is perhaps the more probable view) the existing mammals both in India and in Africa are descended in part from the miocene inhabitants of Europe and Northern Asia, driven southward at the commencement of the cold cycle, which culminated in the glacial epoch, and some genera which have died out in India have survived in Africa. The occurrence of so many species of the Central European miocene beds in the pliocene rocks of Greece is very possibly due to the same migration to the southward.

Origin of Himalayas.—During the interval that has elapsed since eocene times, whilst no important movements, except small and partial changes of elevation, can be traced in the Peninsula, the whole of the gigantic forces, to which the contortion and folding of the Himalayas and the other extra-peninsular mountains are due, must have been exercised. The Sub-Himalayan eocene beds were deposited upon uncontorted palæozoic rocks; and although the Himalayan area was probably in great part land at a much earlier period, there is no reason for believing that this land was of unusual elevation, whilst the direction of the Himalayan ranges is clearly due to post-eocene disturbance. It will be shewn, in the chapters relating to the Sub-Himalayan rocks, that the movement has been distributed over the tertiary and post-tertiary period; and a great portion is of post-pliocene date. Indeed, the fact that earthquakes are now of common occurrence in the Himalayas, the Assam hills, Burma, Cutch, and Sind, and that many of the shocks are severe and some violent, whilst the peninsular area is but rarely affected by earthquakes, may indicate that the forces, to which the elevation and contortion of the Himalayas are due, are still in action; and that the highest mountains in this world owe their height to the fact that the process of elevation is still in progress, to a sufficient extent to counterbalance the effects of denudation.

If, as appears probable, the intercalation of a laterite bed in the Subáthu eocenes shews that the latter strata were of contemporaneous origin with the high-level laterite of the Deccan, which is always posterior in date to the Deccan traps, it is evident that the main Himalayan disturbance is of later date than the Deccan trap period; although the pre-tertiary Himalayan elevation, unaccompanied by folding, may be

older than the traps, or of the same age. In several localities along the base of the Himalayas, basaltic traps are intrusive in the old palæozoic rocks of the mountains. These traps are, however, suspected to be of later tertiary age, and newer than the Deccan traps; for they are said in one locality to penetrate the Sub-Himalayan beds, and in another locality, where Sirmúr beds are entirely composed of detritus from the neighbouring palæozoic strata, no fragments of the trap, now so extensively intruded into those strata, are found. These Himalayan intrusive rocks may be of the same date as the contortion and folding of the beds.

In Sind and the Sulemán ranges, there is much probability that some movement took place during miocene and pliocene times. Some slight unconformity between beds, elsewhere conformable, and the absence of different groups in parts of the country, may thus be explained; but the principal disturbance is clearly of post-pliocene date. To the eastward, in Burma, however, the pliocene formations of the Irawadi valley are but little disturbed, and the miocene beds, although contorted, are unaltered; whilst many of the eocene and cretaceous rocks are greatly changed, besides having undergone excessive disturbance and folding. These facts may, perhaps, indicate that the disturbing forces were more severe to the eastward in middle tertiary times, and that the main action to the westward was of later date: a view partly supported by the fact that there is evidence of elevation having taken place in the Himalayas near the Ganges and Sutlej, at an earlier period than farther to the westward. In the Simla area, there is marked unconformity, due evidently to upheaval and denudation combined, between the Sirmúr and Siwalik series, and between the lower, or Náhan, group of the Siwalik series itself and the next overlying sub-division; whereas farther west, in the Northern Punjab, all the groups follow each other in apparently conformable sequence. The evidence, however, is not sufficient to prove that the contortion to the eastward is older than to the westward; and the absence of any important break in Burma is opposed to the suggestion of great movements having taken place in that country in early or middle tertiary times.

It is evident that the forces, to which the principal ranges in the extra-peninsular area owe their direction, have not only been exerted throughout a considerable portion of the tertiary period, but that these forces have acted contemporaneously, at all events in the post-pliocene period. Yet the directions of the ranges vary in the most remarkable manner, as has already been pointed out on a previous page, and shewn on the sketch map in the commencement of the present Introduction. It would be difficult to conceive clearer evidence: taking only the north-

western area, amongst the mountain ridges that encircle the Indus plain, and comprise pliocene beds, are found ranges running north and south, as the Khirthar and Sulemán; east and west, as the Mari and Bhugti and the Afridi hills; north-west and south-east, as the Pir Panjál; north-east and south-west, as the Eastern Salt Range and Kharian hills; and many intermediate directions may also be traced, independently of curved ridges. Similar differences of direction are to be found to the eastward of India. It is manifest, in the face of so much variation in strike amongst ridges of contemporaneous origin, that arguments in favour of the connexion between distant but parallel ranges should be received very cautiously; and the establishment of cotemporaneous "systems" must depend upon more valid data than the direction of mountain chains.

What the forces can have been that produced the great disturbance and folding of the rocks manifested in the various mountain chains is so difficult a subject, that nothing would be gained by discussing at length the various guesses—for they are little more—hitherto put forward. The only point on which most modern geologists appear to be agreed is, that lateral pressure has been exercised; and by many writers the lateral pressure is attributed to shrinking of the earth's crust, through the cooling of the interior. It is evident, if this be admitted, that the pressure has come, in the case of the extra-peninsular ranges of India, simultaneously from various directions. Even the side from which the force has been exerted in each case is very far from easily determined, owing to the circumstance that the contortion of rocks is due to two opposite and equal pressures—a moving force and a resisting mass—and it is not always easy to distinguish the effect of the one from that of the other. It has been argued by Suess,[1] mainly from the resemblance between the phenomena exhibited by the Sub-Himalayan series, and especially by the Siwaliks, to the south of the Himalayas, and the features shewn by the *mollasse* to the north of the Alps, that the lateral movement, to which the contortion of the Himalayas is due, came from the north, in the same manner as the thrust in the Alps was from the south. This view of Suess, it may be stated, is in accordance with the observations of the Indian Survey, and founded upon them; and if, as appears most probable, lateral movement be accepted as the cause of mountain-formation, the southward thrust of the Himalayan mass may be a correct explanation of the phenomena. The Northern Punjab, west of the Jhelum, as Suess points

[1] Entstehung der Alpen, pp. 126—144. In this valuable work a good summary of the views of previous writers will be found, and abundant references to the literature of the subject. Some remarks bearing on the same matter will be found in Prof. Martin Duncan's Presidential Address to the Geological Society of London in 1877: Proc. Geol. Soc., 1876-77, pp. 67—69, &c.

out, has evidently been affected by a force moving from a different central area, and not by that to which the strike of the Pir Panjál and the Himalayas generally is due. One indication of this difference, and an indication which may shew that the commencement of movement was not contemporaneous in the two areas, is that, east of the Jhelum, in the Pir Panjál, there is a great break at the base of the eocene; whereas west of the Jhelum a similar break, there attributed to a great fault, intervenes between lower and upper eocene beds.

But the curves of the Salt Range, and especially the deep re-entering angle at the Indus, are so much sharper than those of the ranges to the northward, that, despite the smaller degree of disturbance in the Salt Range, there must have been in this area a thrust, or series of thrusts, from the south. This latter force may, of course, have taken the form of resistance to the northern movement; but it exemplifies the difficulty, already referred to, as to the direction of the thrust. Again assuming, as in the absence of all indication of disturbance in tertiary times in the peninsular area we must assume, that this central area remained fixed, and the crust disturbances came from without, we must suppose a lateral movement from the westward on the Western Sind frontier, from the northward in the Mari and Bhugti hills, north of Jacobabad, from the west or west by north again in the Sulemán, from the north in the Safed Koh and Afridi hills, from the north-west in the Hindu Kush and most of the Afghanistan ranges, from the north along the upper Punjab, between Pesháwar and Abottabad, and from the north-east in the Pir Panjál; from the northward throughout the greater portion of the Himalayas, from north-west (or south-east ?) again in the extreme Eastern Himalayas, and from the south-east in the parallel Nága hills; whilst in Burma, as a rule, the thrust has come from the eastward. To the west of India, beyond the Sind frontier, for about 300 miles, the ranges strike east and west, shewing a thrust from north or south; thence throughout the greater part of Persia the direction of the mountain chains is north-west and south-east. The ranges of Baluchistan and Persia,[1] it should be added, are largely composed of tertiary rocks, and may probably be of contemporaneous origin with the Himalayas. Taking the Persian area and that of the Himalaya and Tibet, it will be seen that the mountain ranges fall roughly into two great curves convex to the southward; but the deeper western curve has produced the smaller mountain ranges. That a gigantic lateral movement has taken place in the apex of this western curve is, however, shewn by the fact that for nearly 150 miles between Gwádar and Jálk in

[1] Eastern Persia, I, pp. 1—17, and maps.

Baluchistan the track traverses beds, all apparently of tertiary age, at right angles to their strike, and that all these beds are vertical, or nearly so. The contraction in breadth, or, in other words, the lateral movement, must have been great to have converted horizontal formations into a series of undulations, with dips so high as those seen in the Baluchistan ranges.

Origin of Indo-Gangetic plain.—It would be unprofitable to enter into further discussion on this difficult question: the hypotheses of mountain formation require much to be added before they can be incorporated in the body of geological science, and considered as data on which to found inferences as to the history of the world. But before quitting the subject of the extra-peninsular hill ranges, a few words as to the origin of the remarkable Indo-Gangetic plain, from the outer margin of which they rise, may not be out of place. The popular conception of this plain, an idea repeated in numerous geological and zoological treatises, is that the area is an ancient sea, filled up by deposits brought in by rivers. This view is natural enough: the vastness of the plain, across which, even at its narrowest part, the highest mountains of the world are barely visible, must strike even the most ordinary spectator with its resemblance to a sea-bed. The great contrast between the Himalayan and peninsular formations, and the much greater prevalence of marine beds on the small accessible area of the northern region, also lend weight to the idea of a sea having separated the two.

It should, perhaps, be admitted at once, that, as in the majority of geological speculations, the evidence is imperfect, and the greater portion is negative. There is absolutely no proof of any sort or kind, that the whole Indo-Gangetic plain has at any time been a marine area; but there is equally no proof that it has not. It has been shewn that, in eocene times, the sea occupied the Indus valley as far as the foot of the Himalayas, and extended along what is now the base of the mountains, as far east as Kumaun; and also that marine conditions prevailed to the north-west throughout a great part of the tract now occupied by the Assam range; but it was also pointed out that, in the area between Kumaun and the Gáro hills, no trace of marine formations had been found. Yet it is difficult to understand, if the Gangetic plain was a sea-basin, why no marine beds occur. It is true that the northern border of the plain, throughout the most important part of the intervening space in Nepál, is unfortunately inaccessible to Europeans; but still, if the Gangetic plain in any way corresponds to an eocene sea, as the Indus plain doubtless does, why are no traces of marine beds found to the south of the valley, on the margin of the peninsular area, as they are in the desert to the east of the Indus? In the Brahmaputra plain, also, no

marine deposits of tertiary age are found; in the plain itself only fluviatile deposits have been detected, and the marine eocene and miocene beds are confined to the southern slopes of the range, forming the southern watershed of the valley.

It was shewn that the jurassic traps of the Rájmahál hills, west of the Ganges delta, were very possibly once continuous with those of Sylhet, east of the deltaic area; that the coast line, in cretaceous times, ran from the present eastern coast line of the Peninsula to the Assam Range; and that there is no indication of any cretaceous bay running up the Ganges valley; but, on the contrary, the absence of any marine deposits between Rájámahendri and the Gáro hills rather indicates that the old coast line ran across what is now the Bay of Bengal. It is far from improbable that the nummulitic coast line approximately coincided with that of cretaceous times, as the cretaceous shore nearly followed the old line traced in the upper jurassic period. Miocene marine deposits are to the eastward similarly restricted to eocene, and more so in Western India. As already noticed, it appears certain that those tracts in the Punjab, which had been marine in eocene days, were land in the miocene epoch and in later tertiary times: the immense thickness of upper tertiary beds of freshwater origin, now upraised along the western and northern border of the Indo-Gangetic plain, from the mouths of the Indus to the eastern end of the Assam valley, negative the idea of marine conditions. The occurrence of the same mammals in the pliocene beds of the Sub-Himalayas and of Perim Island has already been noticed as evidence of land communication between the two areas. Amongst still later beds, the post-tertiary formations of the North-West Provinces are clearly river deposits; and in Calcutta itself, within the tidal creeks of the delta, a boring to a depth of 480 feet, 460 being beneath the present sea-level, traversed beds in which the only fossils observed were terrestrial or fluviatile. These beds, moreover, comprised gravel too coarse to have been deposited in an open sea; whilst at 385 feet from the surface a peat bed was found, clearly of terrestrial origin. All tends to shew the gradual depression of an area composed of fluviatile formations throughout all the later tertiary periods. The sea may, at times, have extended some distance from the present coast; for it is improbable that sinking and the deposition of sediment can have gone on so evenly, and that land only just above high water has always been kept at the same relative level, despite ages of depression; but there is nothing in the data known to indicate marine deposits.

In the neighbourhood of the Indus delta the sea probably extended some distance inland at a late period; and both Cutch and Kattywar may

have been islands at a very recent geological epoch. It is clear, however, that the two species of Siwalik elephants, and the buffalo found in the Narbada gravels, could not have traversed the Indo-Gangetic plain, had it been occupied by the sea in pliocene or post-pliocene times. It will be seen that the number and variety of data opposed to the idea of a sea having intervened in the place of the Indo-Gangetic plain between the Peninsula of India and the remainder of Asia during or since the tertiary epoch are considerable, and all the facts are adverse. It must also be manifest that there is no evidence that any such depression as the Indo-Gangetic plain existed in pre-tertiary days; for if it had, we should probably find marine jurassic or cretaceous rocks along the foot of the Himalayas, if not on the margin of the peninsular rock area also.

Thus we are brought in face of a very important conclusion; and it becomes highly probable that the Indo-Gangetic depression is of contemporaneous origin with the disturbance and contortion of the Himalayas and the other extra-peninsular ranges, and that the physical features of the two areas are closely connected. The coincidence in general outline, the parallelism in fact between the great area of depression and the ranges north, east, and west of it, tend to confirm this view. The plain of the Ganges and Brahmaputra continues along the foot of the Himalayas throughout; the Indus plain turning southward where the ranges in the Western Punjab and Sind run north and south, and the estuaries of the Ganges and Brahmaputra being similarly deflected in front of the north and south hills of Tipperah and Chittagong. It is not unreasonable to believe that the crust movements, to which the elevation of the Himalayas, and of the Punjab, Sind, and Burmese ranges are due, have also produced the depression of the Indo-Gangetic plain, and that the two movements have gone on *pari passu*. That the depression of the deltaic area of the Ganges is still in progress, is shewn by a series of facts, of which the evidence afforded by the Calcutta bore-hole is one; and it has already been suggested that the disturbing forces affecting the Himalayas are still in action.

Now, there is a theory, originally attributed to Prévost, but largely adopted and modified by later geological writers, that the elevation of mountains is due to the depression of a neighbouring area. It is clear that if an arc of a circle tends to become flatter, and to approximate to a straight line, the horizontal extent must be increased, because every arc of a circle is longer than its chord. If one portion of a rigid circle be slightly depressed, a neighbouring portion, being compressed into less horizontal space, and having in fact the length of its chord diminished, must bulge out. Applying this fact to the earth's surface, it is clear

that the depression of any portion would produce lateral thrust, and this might cause the bulging of a neighbouring area. Of course, there is a limit: after a certain amount of depression, the arc and chord would coincide in direction, and farther depression would cause the surface to take up less space horizontally, instead of more. The depressions have been called geosynclinals, and the elevations geanticlinals by Dana.

At first sight it would appear as if the theory, as applied to mountain formation, depended partly on the assumption of the earth's internal fluidity; but a little reflection will shew that such is not the case; greater radial contraction of one segment of a sphere, or of one portion of any great circle intersecting the sphere, would depress the surface; and if the superficial portion did not contract equally, would cause lateral pressure. It is assumed, it should perhaps be stated, when changes on the earth's surface are attributed to the shrinkage of the interior through cooling, that the crust, having already cooled, would not contract in proportion.

A very simple calculation, however, shews that the depression, even of so large an area as the Ganges plain, could not have produced the elevation of the Himalayas. The Himalayan belt, between the plains of India to the south and the line of the Indus and Brahmaputra or Sangpo to the north, has an average breadth scarcely, if at all, inferior to that of the Gangetic plain, even if the plateau of Northern Tibet be omitted from the calculation, and supposed to owe its elevation to movements in Central Asia. Assuming that both the Himalayan and Gangetic areas originally differed but little in elevation, it is clear that the Himalayan portion of the arc of a great circle has been raised to the maximum height of the peaks, or 29,000 feet, in addition to all that has been removed by denudation. If the two arcs, that across the Himalayas and that across the Gangetic plain, be approximately equal, in order to produce a lateral thrust sufficient to raise the former, the surface of the latter must be capable of sinking through about an equal distance. The amount is not exactly the same; but in arcs of so small angular dimensions the difference would be trifling. Now, the arc subtended by the Gangetic plain is about 3°, and the height of such an arc of the earth's surface above the chord, or the distance through which the surface could sink and still produce lateral pressure, is only 7,000 feet; whilst the difference in length between the arc of 3° on the earth's surface and the chord of that arc is only about 126 feet. That is to say, the depression of the Gangetic plain could only have produced a lateral movement of 126 feet, and have raised the Himalayas to an elevation of 7,000 feet, provided all the lateral movement was expended in producing elevation.

It is thus evident, independently of the circumstance that the lateral movement appears to have come from the north, that neither the elevation nor folding of the Himalayas is due to the depression of the Gangetic plain alone. The formation of the Indo-Gangetic depression and of the Himalayas and other mountain chains is probably due to the same forces, without the one being in any way the cause or effect of the other.

Distribution of recent fauna.—There is still one question to be noticed before quitting the subject of Indian geological history: this is the light thrown by the distribution of living animals in different parts of the world on former connexions between India and other regions. The geographical distribution of animals has been very fully treated by Wallace,[1] who, following Sclater and some other naturalists, divides the surface of the globe into six great regions: (1) the Palæarctic, including Europe, Africa north of the Sahara, and Asia north of the Himalaya; (2) the Ethiopian, comprising the remainder of Africa, with Southern Arabia and Madagascar; (3) the Oriental, consisting of India, Southern China, Burma, Siam, &c., the Malay Peninsula, the Philippines, Sumatra, Java, Borneo, and the other Malay islands, to "Wallace's line" between Bali and Lombok; (4) the Australian, comprising the south-eastern islands of the Malay Archipelago, Celebes, New Guinea, Flores, Timor, &c., Australia, New Zealand, and all the islands of the Pacific as far east as the Sandwich, Marquesas, and Low Archipelagoes; (5) Nearctic; and (6) Neotropical, approximately corresponding to North and South America.

The classification adopted is open to some objections: the regions named are by no means equivalent to each other, and it is a question whether several do not require further sub-division. The differences between the Indian and Australian faunas, although the two regions are only separated in places by a few miles of sea, are very much greater than the distinctions between the animals inhabiting the comparatively distant Oriental and Ethiopian regions. Several other classifications have been proposed by Murray,[2] Blyth,[3] Von Pelzeln,[4] and others; all of whom agree in classing either the whole Oriental region, or a portion of it, in the same great sub-division with Equatorial and Southern Africa, or else in distinguishing Peninsular India as a region apart. There can be no question about the existence of a marked distinction between the

[1] Geographical Distribution of Animals, 2 vols., 1876.

[2] Geographical Distribution of Mammalia, 1 vol., 1866.

[3] "Nature," 1871, March 30, p. 427; Journ. As. Soc., Bengal, 1875, pt. 2, extra number; Introduction, p. xiv.

[4] Afrika—Indien: Verh. k.-k. Zool. Bot. Gesellsch., Wien., 1875, pp. 62, &c.

fauna of the greater part of the Indian Peninsula and that of the countries east of the Bay of Bengal; but as the question is an open one, it is convenient to adopt Wallace's nomenclature and limits for the present, so far as the great regions are concerned. It must, therefore, be understood that the territories and dependencies of British India, with the exception of the Himalayas, above about 7,000 to 10,000 feet elevation, are classed as belonging to the Oriental region; the higher portions of the mountains, together with the trans-Himalayan countries, belonging to a province of the Palæarctic region. In North-Western India, however, there is so large an admixture of Palæarctic forms, that no definite line can be drawn between the two faunas; Kashmir, for instance, and the North-Western Punjab near Peshāwar, having almost an equal proportion of types belonging to the two.

It is, however, impossible to assent without modification to the subdivisions or sub-regions of the Oriental region proposed by Wallace. They are four in number: (1) the Hindustan or Indian sub-region; (2) the Ceylonese and South Indian; (3) the Himalayan or Indo-Chinese; and (4) the Indo-Malayan. The Himalayan includes Siam, Southern China, and all Burma, except the extreme southern portion of Tenasserim: the latter, with the Malay Peninsula, belongs to the Indo-Malayan sub-region. This division between the two sub-regions, so far as British territories are concerned, is correct; and the minute details of the great Indo-Chinese subregion are not of so much geological interest as the distribution of the fauna in the Indian Peninsula and its outskirts. From Wallace's Indian sub-region the Indus plain and the desert to the eastward must be separated and classed with the Baluchistan coast-land as a distinct subregion, having a characteristic dry climate fauna and flora, with a large intermixture of Palæarctic forms; whilst the limits of the Ceylon and Southern Indian province require alteration. This sub-region, a very important one, with a peculiar fauna, having some marked affinities to that of the Malayan countries, comprises the whole Western or Malabar coast of the Peninsula, from north of Bombay to Cape Comorin; but not the central highlands nor the Coromandel coast, although several isolated hill-groups, such as the Shivarais, south-west of Madras, possess, on their higher elevations, a Malabar fauna and flora. This sub-region is better distinguished by the name of Malabar; it comprises the hills of Southern Ceylon, but not the plains forming the northern portion of the island.

It is of course unnecessary to enter here at any length into the peculiarities of the fauna: the points to which attention is desirable is such evidence of former connexion with regions, now separated by impassable

barriers, as is afforded by the existence of allied animals. As might be anticipated, a few Palæarctic forms are common in those parts of the Oriental region nearest to the Palæarctic boundary, and the number of such forms diminishes to the southward.

The importance of these types is derived from the fact, that they require careful distinction from Ethiopian genera; for there is a similar admixture of Palæarctic forms in the Ethiopian region. In the same manner several distinctively Malayan and Himalayan forms, of birds especially, are common in the Indian Peninsula, independently of the peculiar forms with Malay affinities in the Malabar sub-region; and it is probable that Malayan forms are, in many cases, recent immigrants.

Mammals and reptiles, owing to their more limited powers of migration, afford better indications of a former continuity of land than birds; whilst freshwater fishes and other animals inhabiting rivers and lakes suffer from the serious disadvantage that, whilst the exact method by which they, or their ova, are transported, is not clearly understood, there is no doubt that they are capable of being carried alive from one piece of water to another by some natural agency. Hence the limits to their range are imperfectly known. The past history of land invertebrates is too imperfectly ascertained for the facts of their present distribution to be equally intelligible with that of vertebrates. On the whole, although the past history of mammalian vertebrates is still very imperfectly understood, it probably affords more data by which the probable migrations and origin of living species can be traced, and inferences drawn as to the original distribution of land, than does the existing knowledge of any other class of animals.

Ethiopian affinities of Oriental mammals.—Comparing, then, the mammalian fauna of the Oriental region, as a whole, with that of the three neighbouring regions, it will be found at once, that the strongest affinities are with the most distant of the three—the Ethiopian. Out of 35 families of terrestrial *Mammalia* ascribed to the Oriental region by Wallace, four are peculiar, or nearly so, viz., *Tarsiidæ*, *Galeopithecidæ*, *Tupaiadæ*, and *Æluridæ*; one, *Tapiridæ*, is found also in the Neotropical region only, and six only (excluding stragglers in Celebes, and one or two of the other islands having an intermediate fauna) are found in the Australian region; four of these being bats, and a fifth, *Suidæ*, only extending beyond the confines of the Oriental region as far as New Guinea; so that the only terrestrial wingless mammalian family common throughout is the almost cosmopolitan *Muridæ*. The number of Oriental families found in the Palæarctic region is 21, whilst no less than 28 are common to the Oriental and Ethiopian faunas. Omitting such cosmopolitan families

as *Vespertilionidæ, Soricidæ, Muridæ, Felidæ,* &c., the numbers are 13 and 19. The families found in the Oriental and Palæarctic regions, but not in the African, are *Talpidæ,* almost confined in the former to temperate portions of the Himalayas and some other hill ranges, *Ursidæ* and *Cervidæ.* The families found in the Oriental and Ethiopian regions, but not in the Palæarctic, are *Simiidæ, Semnopithecidæ, Lemuridæ, Pteropidæ, Noctilionidæ, Manatidæ, Rhinocerotidæ, Tragulidæ, Elephantidæ,* and *Manididæ.* A species of *Semnopithecidæ* is found at a high elevation in Eastern Tibet, and another species ranges above most Oriental forms in the Himalayas; but in neither case can the animal be said to inhabit the Palæarctic region.

Of these families, the bats and dugongs may be neglected; the other families require a few words of notice. The *Simiidæ* are wanting in the Indian Peninsula, Ceylon, and the Himalayas. The *Semnopithecidæ* occur almost throughout the region; the *Lemuridæ* are represented by one genus confined to Southern India and Ceylon, and by a second genus in the countries east of the Bay of Bengal: none occur in the Himalayas, nor in the greater part of Peninsular India. The *Rhinocerotidæ* are unknown wild in the Indian and Malabar sub-regions; the *Tragulidæ* are represented by one genus or sub-genus in India and Ceylon, and by another in the countries east of the Bay of Bengal: this family, also, is not represented in the Himalayas. The *Elephantidæ* and *Manididæ* are more generally distributed. The *Rhinocerotidæ* and *Elephantidæ* had so extensive a distribution in the later tertiary period, that they furnish no inference of importance as to the former connexion of land areas; the ancestor of the existing Oriental species might have been derived from either the Palæarctic or Ethiopian region.

One remarkable fact may be gathered from these few details; and this is, that the peculiarly Ethiopian families are better represented to the south and east of the Oriental region than to the north-west. The orangs, the nearest allies of the African *Simiidæ,* are only found in Sumatra and Borneo; the lemurs are wanting throughout the northern portion of the region, and so is *Tragulus.* These forms, in fact, appear more or less isolated, as though they had formerly had a more extended range. The same thing occurs in Africa. The only Ethiopian representative of the *Tragulidæ* is confined to Western Africa; and so are the two genera of lemurs most nearly allied to the Oriental forms, and the African representative of the typically Oriental genus *Paradoxurus.* The *Simiidæ,* too, are confined to Western and Central Africa. Another curious instance of the isolation of types shewing affinity between the African and Malay faunas consists in the occurrence in Celebes, beyond the limit of the

true Oriental region, and associated with a mixed Oriental and Australian (Austro-Malay or Papuan) fauna, of a monkey, *Cynopithecus,* more nearly allied to the African baboons than to any of the Indian and Malay species. The same island possesses the peculiar bovine form *Anoa,* allied to a buffalo.

These cases of isolation probably indicate that the animals belong to an older fauna, now partly replaced by newer types, and that this older fauna was common to India and Africa. It is very probable that these animals are descended from the ancient tropical fauna of the early tertiary times. But, so far as it is possible to judge, the process of variation would have caused a greater distinction between forms so widely separated, and exposed to such different conditions, if the period of isolation were great; and it is difficult to suppose that the lands inhabited by the ancestors of the *Simiidæ, Lemuridæ, Tragulidæ,* and *Manididæ* of the Oriental and Ethiopian regions can have been separated prior to the early part of the miocene period.

It must be remembered that the whole evidence is far more extensive; the mammalia are merely selected as affording the best examples. It may reasonably be inferred that during part of the early tertiary period India was united to Africa, and the union may have been continuous from the cretaceous period to miocene times. The course of the old continent may perhaps be traced by the Maldive and Chagos archipelagos, and by the banks between the Mascarene islands and the Seychelles. That portions of the old land remained, broken up into islands, long after the connexion had been severed, is probable from some peculiarities amongst the birds of the Seychelles and Mascarene islands: thus the genus *Hypsipetes,* a characteristically Oriental form, is represented in Madagascar, Bourbon, Mauritius, and the Seychelles; and *Copsychus,* an equally typical Eastern genus, occurs also in Madagascar and the Seychelles. It is easily conceivable that birds should fly, or be blown, from island to island long after the distance was too great to be traversed by mammals. The circumstance that the mammalian fauna of the Oriental region shews less affinity with Madagascar than with that of the African continent, is perhaps due to Madagascar having been separated before the submergence of the land connecting Africa and India.

The southern portion of the Indian Peninsula with Ceylon may have been united to the Malay countries in tertiary times, perhaps later than with Africa. This, however, is not clear: despite some remarkable points of affinity to the Malay fauna, there are very remarkable differences; and when representative forms are found in Southern India or Ceylon and in the Malay countries, such forms are frequently, perhaps most fre-

quently, generically distinct. One of the most singular cases of generic alliance is the occurrence of a species of *Draco*, a Malay genus of lizard, in Malabar; but this is exceptional. Most of the genera of Ceylonese and Southern Indian lizards and snakes are peculiar; and one family of snakes is confined to the sub-region, and to some hill tops in Southern India. So far as the sea bottom between Ceylon and the Malay archipelago is known, there is nothing to indicate a former continuity of land in this direction; and the similarity of the fauna may perhaps have another explanation.

Ethiopian affinities of Indian mammals.—The affinities with the Ethiopian fauna hitherto mentioned are those of the Oriental region generally, and are, as already noticed, perhaps more marked in the southern part of that region than elsewhere; but, besides these, there are some very curious and prominent relations between the mammals and other animals of Africa and those inhabiting the Indian Peninsula alone, and not represented by any allied forms in the other Oriental sub-regions. As examples, the common antelope, *Antilope,* the nilgai, *Portax,* the four-horned antelope, *Tetracerus,* and the ratel, or Indian badger, *Mellivora,* may be quoted. In the case of *Mellivora,* the resemblance of the African and Indian forms is very great; but the antelopes are generically distinct. None of the animals mentioned is represented by allied species in Baluchistan or Arabia. These alliances to the African fauna may indicate that the Peninsula of India was united to Africa after the Malay countries had been severed; and if so, the evidence just quoted in favour of a later union between Southern India and Malayasia must receive some other explanation; but the Indian antelopes may very possibly be descendants of forms inhabiting the region in pliocene times; and the resemblance of these animals to Ethiopian types may be due to the immigration, as already suggested, of a closely allied fauna into both India and Africa at the close of the miocene epoch.

A third class of Ethiopian affinities in the fauna of Peninsular India is exemplified by the Indian gazelle and Jerboa rat (*Gerbillus*). In this case, however, closely allied species are found in the intervening countries and in the southern Palæarctic region; and the migration into India may have been posterior to the glacial epoch.

Affinities of land shells.—It should have been mentioned that the affinities of Oriental genera of land shells, and especially of the operculate forms (*Cyclophoridæ* and *Helicinidæ*), indicate an alliance with the Australian, rather than with the African fauna. Some genera certainly have extended to the Mascarene islands, Madagascar, and Africa; but they probably went from east to west, as the number decreases to the

westward. Land mollusca are very possibly of high antiquity; and the resemblance in this case may be due to the older mesozoic communication between India and Australia. The mode of migration of these animals is, however, imperfectly understood.

Survival of older types in the Indian area.—This is perhaps the most convenient place to call attention to the survival of forms in India to a later period than in Europe; several such instances of prolonged existence have been noticed, and they are not peculiar to any particular period of geological time. Amongst the cases hitherto recorded is the appearance of *Hyperodapedon*, a triassic reptile, in Indian beds of middle or upper jurassic age, and the occurrence of the triassic *Ceratodus*, and of some liassic genera of fish in the same beds. Then middle jurassic plants in Europe occur in upper jurassic beds in India; *Globosi* ammonites, not known above the trias in Europe, are found in middle cretaceous rocks in India; *Megalosaurus* and an amphicœlian crocodile, not found above lower cretaceous in the former area, are met with in upper cretaceous strata in the latter. The appearance of miocene European forms in the pliocene Siwaliks, and the existence at the present day of mammals, like elephants and rhinoceroses, on land, and of numerous marine molluscan genera in the seas of India, long after they have disappeared from the European area, are additional examples. The cases are not sufficiently numerous to indicate any law of migration from north to south, nor is the tendency to survival in India universal; for, on the other hand, *Voltzia heterophylla* and the other Karharbári plants probably occurred in India before they appeared in Europe; and several genera of *Gasteropoda* that abound in the Indian upper cretaceous beds are not found in Europe in older rocks than eocene. Still the instances of survival of older forms in India are sufficiently numerous to be worthy of mention: how far they are due to the tropical position, or to the great antiquity of the land area, it is difficult to say.

Glacial epoch.—Amongst the most potent disturbing causes that have affected the fauna of India in late geological times, the general refrigeration of the area in the glacial epoch has in all probability played a conspicuous part. The former extension of the Himalayan glaciers has been shewn to have been considerable; and the occurrence of Himalayan plants and animals on the higher ranges of Southern India may be due to the retreat of these species in the first place towards the equator, and subsequently, as the temperature increased, to the higher parts of the hills. As examples, the occurrence of a Himalayan rhododendron, of a wild goat allied to a Himalayan species, and of several Himalayan land shells on the Nilgiri and other Southern Indian hills

may be mentioned. The isolation of such forms of the ancient Indo-African fauna as the *Simiidæ*, *Lemuridæ*, and *Tragulidæ* may have been due to the irruption of the Siwalik fauna, in pliocene times; whilst the latter, in its turn, has been impoverished, and to a great extent exterminated, by the increasing cold of the glacial epoch. It is easy to understand how the remaining descendants of the old miocene fauna may have been driven to the tropics, and that thus their absence in the northern part of the Oriental region has been caused. It is not impossible that the distinction between the Malabar and Malay faunas has been intensified by their separation, due to the climate of Northern India having been too cold for them in the glacial epoch.

Sub-recent changes of level.—The evidence of recent changes in elevation on the shores of the Indian Peninsula, and also to the westward, along the Makrán coast, and to the east of the Bay of Bengal, on the shores of Arakan and of the islands in the Bay, indicates a rise of land. In places depression to a small extent has also taken place; but this is unusual, and apparently local; it is singular, however, that evidence of depression is found in one instance, in Bombay Island,[1] within a mile or two of land, which has apparently been raised. The Sahyádri scarp, at a little distance from the west coast, has much the appearance of an ancient sea-cliff, and may perhaps indicate a former coast line; but this is far from certain. The circumstance, that the low-level laterite in the neighbourhood of both coasts rests upon a sloping plane of rock, apparently formed by marine denudation, in all probability indicates elevation at no distant period; the laterite in question being certainly post-tertiary on the east coast, and probably on the western also. The elevation on the west coast may probably have been greater than on the eastern, as the laterite near the coast is raised to a higher level; and in the great rivers running westward, the Tapti and Narbada, large plains of post-tertiary deposits are found, one of which certainly has been accumulated in a rock-basin, whilst no such plains are found in the rivers running eastward.

Along the Makrán coast, to the west of India, there is a sub-marine cliff, at a distance of about 10 to 20 miles from the shore. This cliff extends from a little west of Cape Monze to the entrance of the Persian Gulf, and is about 2,000 feet high; the depth of the sea increasing more or less suddenly from 20 or 30 fathoms to 300 or 400. Without further

[1] The evidence of depression has been noticed since pp. 375–377 were printed off, and consists of the discovery of a large number of trees, imbedded in mud on the spot where they grew, with their roots at a depth of twelve feet below low-water mark, on the eastern or harbour side of Bombay Island. Rec. G. S. I., XI, p. 302. Similar evidence was recorded, some years ago, by Dr. Buist.

details, it is difficult to say whether this sub-marine cliff indicates depression: such would be the natural interpretation of the phenomenon, and it is, on the whole, most probable that a former coast line of sea-cliffs has been depressed; but there is, in several places along the coast, evidence of recent elevation, in the shape of raised shell beds, &c., and there is a possibility that the line of sub-marine cliffs may be a fault. On the Arabian coast of the Gulf of Omán, however, about Muscat and the Straits of Hormuz, there is abundant evidence of depression at no distant period. The depressed area in the ocean south-west of India, as indicated by the Laccadive, Maldive, and Chagos atols, has already been noticed as possibly indicating the area of the ancient land communication between India and Africa.

Previous summaries of Indian geology: Calder, 1833.—Before concluding this Introduction, a brief notice of former general descriptions of Indian geology may be useful. Such general accounts are not numerous, and a reference to them will not take much space.

The earliest attempt at a sketch of Indian geology was written by Mr. James Calder, and forms the first paper of the Eighteenth Volume of the Asiatic Researches, published in 1833. This volume is chiefly composed of geological papers, and to these Mr. Calder's forms, as it were, an introduction. In this account, which occupies only 23 pages, the general distribution of the overlying trap formation in Western and Central India, and the great prevalence of granitic and gneissic formations both in the Peninsula and throughout the Himalayas, are correctly indicated; but, as might be anticipated, the knowledge of the sedimentary formations of India was at that time very imperfect. The writer passes the different provinces in review, noting what had been ascertained as to the rocks occurring in each case.

Newbold, 1844-1850.—The next account refers to the southern part of the Peninsula alone; but it is the work of one of the best, if not actually the best, of the earlier Indian geologists; and it has the peculiar advantage over all other summaries published up to the present time, that the author possessed an extensive personal acquaintance with the country described. Captain Newbold's Summary of the Geology of Southern India is published in Volumes VIII, IX, and XII of the Journal of the Royal Asiatic Society, and treats of the area south of Bombay and Ganjam. The various formations are classed as the Hypogene series (the metamorphic rocks of the present work); diamond sandstone and limestone (including the transition and Vindhyan series and some Gondwána beds); the fossiliferous limestone of Pondicherry (cretaceous); fresh-

water limestones and cherts (intercalated with the Deccan traps); laterite, with which are associated, in one section, the Pondicherry silicified wood deposit (Cuddalore sandstone) and the marine sandstone beds of Ramnád and Cape Comorin; older alluvium, including regur and kankar; modern alluvium and sand dunes; plutonic rocks (granite, greenstone, &c.); and newer or overlying trap.

The most important error in this classification was the association of the rocks now classed in the Gondwána system with the ancient "diamond sandstone" of transition or Vindhyan age. This appears due to Captain Newbold's having no personal knowledge of the Gondwána beds, and to their having been confounded with the older rocks by previous observers. Most of the observations recorded in the Summary are admirable; and altogether the paper is so valuable, that the neglect with which it has been generally treated, and the much greater notice attracted by Dr. Carter's account, are not easy to understand. Captain Newbold's observations will be frequently noticed in the present work.

Carter, 1854.—Dr. Carter's "Summary of the Geology of India between the Ganges, the Indus, and Cape Comorin," first published in 1854 in the Journal of the Bombay Branch of the Royal Asiatic Society, Vol. V, pp. 179–335, and republished with additional notes in 1857 in the author's very useful reprint of "Geological Papers on Western India," is a compilation of great merit, and is much more generally known, in India at all events, than Captain Newbold's description of the geology of Southern India; but it cannot be said to equal the latter, either in accuracy or originality. Dr. Carter's Summary treats of a larger area than Captain Newbold's—of the whole of Peninsular India, in fact; but it suffers from the serious disadvantage that the author was personally acquainted with but an extremely limited tract in Western India, that he had never seen the vast majority of Indian formations, and that he was compelled to take the whole of his description from other writers.

The rocks of the Indian Peninsula are classed by Dr. Carter in 13 sub-divisions: (1) The Primitive Plutonic Rocks; (2) Older Metamorphic Strata; (3) Secondary Plutonic Rocks; (4) Cambrian and Silurian Rocks of M'Clelland; (5) Oolitic Series; (6) Cretaceous System; (7) Eocene Formation; (8) Volcanic Rocks (Trappean System, first series); (9) Inter-trappean Lacustrine Formation; (10) Volcanic Rocks (Trappean System, 2nd series); (11) Miocene and Pliocene Formations; (12) Post-pliocene Period; (13) Recent Formations. This classification is inferior in accuracy to Captain Newbold's. It was an unfortunate mistake to class the Gondwána rocks with the Transition and Vindhyan formations; but it was still more erroneous to call the latter "oolitic." Dr. Carter, depending upon

the descriptions, tried to classify the different deposits of his "Oolitic series" in three groups, termed respectively Tara, Kattra, and Panna, from localities in Bundelkhand, and much confusion has hence arisen. The classification of the metamorphic rocks also is artificial; and the subdivision of the volcanic rocks into two series, the intercalation of the intertrappean lacustrine series between the two, and the position assigned to the eocene rocks below, instead of above the traps, have all proved to be incorrect. Even where Dr. Carter was personally acquainted with the rocks, his views have not always been confirmed by subsequent research. Thus the traps of Bombay and Salsette were classed as intrusive; whereas almost all other observers agree in considering these beds as resting regularly, with their intercalated sedimentary beds, upon the older lava flows of the Deccan; and there can be no doubt that this is the correct view, the dip of the Bombay beds being due to disturbance after their consolidation.

Attention is called to these grave errors in Dr. Carter's paper from no wish to criticise his work harshly, but because, owing to the numerous merits of the "Summary," his views have been widely accepted, and are still quoted as valid in recent works: for instance, in Dr. Leith's description of the geology of Bombay, just published in the *Bombay Gazetteer*. In many respects Dr. Carter's Summary was a most valuable compilation; and, with the exception of the mistake about the rocks of Bombay, all the errors were due to the imperfection of the observations from which the work was compiled. The labour of compiling a general description of Indian rocks from the fragmentary materials available at the time was very great; and by the compilation of his Summary, by the republication of the various geological papers on Western India, and by the collection of numerous valuable notes in the Journal of the Bombay Branch of the Royal Asiatic Society, Dr. Carter gave most important aid to Indian geology.

Greenough, 1854.—Mr. Greenough's Geological Map of India was exhibited to the British Association in 1854, and published shortly after. The author had endeavoured to combine all published information as to the distribution of Indian geological formations; and the result was a map which did represent fairly the areas occupied by some of the principal formations, such as the metamorphic rocks and the Deccan trap; but which, owing to the very imperfect knowledge available at the time, was deficient in details, even with respect to those formations, and which contained many errors both in topography and the distribution of the rocks. Still the map, although it does not quite represent the knowledge available at the time of its publication, is a very valuable record of the amount

procurable by a careful recorder working in Europe. In presenting the map to the British Association, Mr. Greenough gave a brief sketch of the rocks known to occur in India. This sketch will be found at page 83 of the transactions of the sections, in the Report of the Twenty-fourth Meeting of the British Association, published in 1855.

Later sketches.—Although the date of publication of the last two works, Carter's Summary and Greenough's Map, is posterior to that of the commencement of regular survey operations under the late Dr. Oldham, the work of surveying had commenced too short a time for the results to be appreciable; and the description and map named represent, the former more adequately than the latter, the knowledge of Indian geology existing when systematic surveying was commenced. Surveys of isolated tracts had previously been made by Captain Herbert, Mr. Williams, Dr. M'Clelland, Dr. Fleming, and others for Government; but the regular examination of the country can scarcely be said to have commenced before 1851, if indeed its origin should not be placed somewhat later. The only general descriptions since published are by various officers of the Survey. A digest of the geological information published up to the time was printed by Professor Martin Duncan for the use of students at Cooper's Hill College, but was not published. A brief sketch of Indian geology was given in Mr. H. F. Blanford's "Rudiments of Physical Geography for the use of Indian Schools." Lastly, whilst the present work has been passing through the press, Dr. Waagen, who, like Mr. H. F. Blanford, belonged formerly to the staff of the Indian Geological Survey, has published a short general description of the geology of India, entitled "Ueber die geographische Vertheilung der fossilen Organismen in Indien" in the "Denkschriften" of the Imperial Academy of Sciences, Vienna. All these papers are founded, like the present work, on the survey observations, and consequently require no detailed notice.

List of European formations.—In the following pages it will often be necessary to refer to particular beds in Europe. The following is a list, arranged in the accepted sequence, of the groups and minor formations, in England, France, Germany, and some other parts of Europe, most commonly referred to in geological works. The list is taken in great part from that in Lyell's Elements of Geology, but is shorter; whilst a few formations, important for the correlation of Indian rocks, are added, and a few foreign terms. The omission of all mention of a group in any column by no means indicates the absence of the formation in the country to which the column refers, nor are the groups noted necessarily exact equivalents of each other.

		Great Britain and Ireland.	France and Belgium.	Germany, Austria, Switzerland, Italy, &c.	
Post-tertiary or Quaternary.	*Recent* ...	Newer alluvial gravels. Peat mosses, &c.	Terrain moderne (D'Archiac).	Alluvium, &c.	
	Pleistocene.	Cave deposits. Glacial drift.	Terrain quaternaire ou diluvien (D'Archiac). Formation erratique.	Diluvium. Loess of Rhine, &c.	
Pliocene ...	*Newer* ...	Boulder clay and older glacial drift. Norwich crag.			Neocene (Neocän) or Neogene.
	Older ...	Red crag. Coralline crag.	*Subapennin.* Antwerp crag.		
Miocene ...	*Upper* ...	*Wanting.*	*Falunien.* Faluns of Touraine and Bordeaux.	Beds of Vienna basin. Marine Mollasse of Switzerland.	
	Lower ...	Hempstead beds.	Calcaire de la Beauce. Grès de Fontainebleau.	Beds of Mayence basin. Brown coal of Northern Germany. Lower Mollasse of Switzerland.	Oligocene (Oligocän).
Eocene ...	*Upper* ...	Bembridge, Osborne, and Headon beds. Barton beds.	Gypsum of Montmartre. Calcaire silicieux. Grès de Beauchamp ou Sables moyeus. } *Parisien.*	Flysch of Alps.	
	Middle ...	Bracklesham beds and Bagshot sands.	Calcaire grossier. Lits coquilliers.	Nummulitic limestone.	
	Lower ...	London clay. Woolwich and Reading beds. Thanet sands.	*Suessonien.* Argile plastique. Sables de Bracheux.	Ronca beds.	

CRETACEOUS	Upper		Upper white chalk with flints Lower white chalk	*Danien*: Maestricht beds: craie pisolitique. *Senonien*: craie blanche.	Gosau beds. Pläner.	
			Chalk marl Upper greensand	*Turonien*: craie tufau: craie chloritée. *Cenomanien*: grès vert: Tourtia.	Hippuritic limestone. Quader.	
			Gault Blackdown beds	*Albien.*		
	Lower		Lower greensand. Speeton clay. Weald clay. Hastings sands.	*Aptien.* *Neocomien.*	Hils conglomerat. Hilsthon. Wealden of Hanover.[1]	
JURASSIC	Upper	*Upper oolite.*	Purbeck beds Portland stone and sand Kimmeridge clay	*Portlandien.* *Kimmeridgien.*	White Jura or Malm. Solenhofen beds.	
		Middle oolite.	Coral rag Oxford clay Kelloway rock	*Corallien.* *Oxfordien.* *Callovien.*		
	Middle	*Lower oolite.*	Cornbrash and forest marble Bath or great oolite Stonesfield slate Inferior oolite	*Bathonien.* *Bajocien.*	Brown Jura or Dogger.	
	Lower	*Lias.*	Upper lias Shale and limestone Middle lias or marlstone Lower lias	*Toarcien.* *Liasien.* *Sinemurien.*	Black Jura or lias; Hierlatz beds.	
TRIASSIC	Upper		Rhætic, Penarth or *Avicula contorta* beds	... ...	Dachstein limestone. Kossen beds.	Rhætic.
			Upper new red sandstone. Red shales with rock-salt. Dolomitic conglomerate of Bristol.	*Saliferien.* Marnes irisées.	Haupt dolomit and Raibl beds. Lettenkohle. Hallstatt beds. St. Cassian beds.	Keuper.
	Middle		Wanting.	*Conchylien.*	Muschelkalk. Wellenkalk.	
	Lower		Lower new red sandstone (part).	Grès bigarré.	Bunter sandstone.	

[1] By many German geologists the Wealden is classed as Jurassic.

		GREAT BRITAIN.	FRANCE AND BELGIUM.	GERMANY, AUSTRIA, SWITZERLAND, &c.
PERMIAN OR DYAS		Lower new red sandstone (part). Magnesian limestone and marl slate of Durban, &c. Trappean, breccia and red marls.	*Permien* or *Penéen*. Grès des Vosges.	Zechstein. Kupferschiefer. Rothliegendes, or Rothes Todtliegendes.
CARBONIFEROUS ...	Upper ...	Coal-measures of England and Wales. Millstone grit. Yoredale series of Yorkshire.	*Carboniférien*. Terrain houillier.	Steinkohl system.
	Lower ...	Mountain limestone. Lower coal-measures of Scotland. Lower limestone shale or carboniferous slate.		Culm.
DEVONIAN ...		Old red sandstone. Sandstones of Dura Den. Yellow sandstones of Ireland. Petherwyn group of Cornwall. Pilton, Ilfracombe and Lynton groups of Devonshire.	*Devonien*.	Grauwacke. Limestone of Eifel.
SILURIAN ...	Upper ...	Upper Ludlow and Downton limestone with bone bed. Aymestry limestone. Lower Ludlow. Wenlock limestone and shale. Woolhope limestone and grit. Upper Llandovery or May Hill sandstone. Lower Llandovery slates.	*Silurien*.	......
	Lower ...	Bala or Caradoc beds. Llandeilo flags. Arenig or stiper-stones group.		
CAMBRIAN ...	Upper ...	Tremadoc slates. Lingula flags.	......	Premordial zone of Bohemia.
	Lower ...	Menevian beds. Longmynd group. Harlech grits and Llanberis slates.		
LAURENTIAN ...	...	Fundamental gneiss of Hebrides.	......	......

Classification of animal kingdom.—For purposes of reference, and as a key to some of the lists of fossils, the following table, shewing the arrangement of subkingdoms, classes, subclasses, and orders of animals, may be useful. The system is that of Professor Huxley, as proposed in his "Introduction to the Classification of Animals."

Subkingdoms.	*Classes.*		*Orders.*	
I. VERTEBRATA	1. MAMMALIA		Primates.	
			Insectivora.	
			Chiroptera.	
			Carnivora.	
			Rodentia.	
			Proboscidea.	
			Hyracoidea.	
			Ungulata.	
			Cetacea.	
			Sirenia.	
			Edentata.	
			Marsupialia.	
			Monotremata.	
	2. SAUROPSIDA	(a) *Aves*	Saururæ.	
			Ratitæ.	
			Carinatæ.	
		(b) *Reptilia*	Crocodilia.	
			Lacertilia.	
			Ophidia.	
			Chelonia.	
			Ichthyosauria	Enaliosauria.
			Plesiosauria	
			Dicynodontia.	
			Pterosauria.	
			Dinosauria.	
	3. ICHTHYOPSIDA	(a) *Amphibia*	Urodela.	
			Batrachia.	
			Gymnophiona.	
			Labyrinthodonta.	
		(b) *Pisces*	Dipnoi.	
			Elasmobranchii.	
			Ganoidei.	
			Teleostei.	
			Marsipobranchii.	
			Pharyngobranchii.	
II. MOLLUSCA	1. CEPHALOPODA		Dibranchiata.	
			Tetrabranchiata.	
	2. PTEROPODA.			
	3. PULMOGASTEROPODA or *Pulmonata*.			
	4. GASTEROPODA (*Branchiogasteropoda*).			
	5. LAMELLIBRANCHIATA (*Pelecypoda*).			
III. MOLLUSCOIDA	1. ASCIDIOIDA		Branchialia.	
			Abdominalia.	
	2. BRACHIOPODA		Articulata.	
			Inarticulata.	
	3. BRYOZOA or *Polyzoa* (*Ciliopoda*).		Phylactolœmata.	
			Gymnolœmata.	

Subkingdoms.	*Classes.*		*Orders.*
IV. CŒLENTERATA	1. Anthozoa or *Actinozoa*		Ctenophora. Coralligena.
	2. Hydrozoa		Hydrophora. Siphonophora. Discophora.
V. ANNULOSA or *Articulata.*	1. Insecta	Arthropoda.	Coleoptera. Hymenoptera. Lepidoptera. Diptera. Hemiptera. Strepsiptera. Trichoptera. Neuroptera. Orthoptera.
	2. Myriapoda	Arthropoda.	Chilopoda. Chilognatha.
	3. Arachnida	Arthropoda.	Arthrogastra. Araneina. Acarina. Arctisca or Tardigrada. Pycnogonida. Pentastomida.
	4. Crustacea	Arthropoda.	Podophthalmia. Branchiopoda. Ostracoda. Pectostraca. Stomapoda. Edriophthalmia. Merostomata. Copepoda. Trilobita.
	5. Annelida		Chætophora. Discophora.
	6. Chœtognatha.		
VI. ANNULOIDA	1. Scolecida		Trematoda. Tæniada. Turbellaria. Acanthocephala. Nematoidea. Rotifera.
	2. Echinodermata		Echinidea. Holothuridea. Asteridea. Ophiuridea. Crinoidea. Cystidea. Edriasterida. Blastoidea.
VII. INFUSORIA	1. Infusoria.		
VIII. PROTOZOA	1. Spongida or Spongiozoa.		
	2. Radiolaria (including *Polycistina*).		
	3. Rhizopoda (including *Foraminifera*).		
	4. Gregarinida.		

ERRATA.

N. B.—Several discrepancies in the spelling of Indian names have crept into the text as was hardly to be avoided under the circumstances (see Preface): any that might mislead are noticed by cross-references in the Index.

Page 15, line 16, *for* "trap dyke," *read* "trap dykes."
„ 114, „ 17, *for* "*Noeggerathin,*" *read* "*Noeggerathia.*"
„ 141, in table, *for* "Budhanada," *read* "Budhavada."
„ 149, line 5, *for* "lower jurassic," *read* "middle jurassic or lower oolitic."
„ 159, „ 15, from bottom, *for* "*Pecopteris whitbyensis,*" *read* "*Alethopteris whitbyensis.*"
„ 288, „ 7, from bottom, *for* "LUCINDIDÆ," *read* "LUCINIDÆ."
„ 315. The statement that *Lymnea* is not found in deep water proves erroneous, animals of this genus having been dredged living from a considerable depth in the Lake of Geneva.
„ 343, and p. 393, *omit* "*Mastodon sivalensis*" from the lists of fossils found in Perim Island.
„ 345, line 19, *for* "Chobar," *read* "Chorar."
„ 490, „ 14, "*Productus spinosus*" is perhaps quoted by mistake for some allied species.
„ 732, „ 18, *for* "Malay peninsula," *read* "Malay archipelago."
" 150, at top, add "The following is"
" 153 & 154, figures, for mangli read Maleri.

MANUAL OF THE GEOLOGY OF INDIA.

CHAPTER I.

PENINSULAR AREA.

AZOIC ROCKS—GNEISSIC OR METAMORPHIC SERIES.

Introductory remarks:—Three-fold division of azoic rocks — Three gneissic regions — Main region, south and east, including Assam — Bundelkhand region — Arvali region — A key section — General composition and distribution of azoic rocks. Bundelkhand gneiss: Composition of the gneiss — The schists — Granitic veins — Quartz reefs — Trap dykes — Accessory minerals — Contiguous formations. Main gneissic region: Bengal area — Singhbhum area — Orissa area — Central Provinces — South Máhratta area — The Southern Konkan — The Wainád — The Nilgiris — Trichinopoli and Arcot — Assam area. Arvali.

Introductory remarks.—In most countries the disappearance of organic remains is gradual, as we descend in the series of stratified formations. The rocks become more and more altered, by compression and chemical transformation, from their original condition as sediments, and the organic forms they once enclosed have thus been obliterated. This general fact makes way for the opinion now prevalent—that the oldest known fossils are the descendants of forms for ever lost to observation. In India, as a rule, there is a very abrupt contact between the most ancient rocks which have been so much altered as to have become uniformly crystalline and other very ancient formations which have undergone comparatively little change; showing that the former had already been metamorphosed when the latter were deposited. There are also, in this country, some cases of gradual transition between the crystalline metamorphic rocks and the slightly affected strata of adjoining areas. We have, however, to pass through many upward stages of transition rocks, and to cross a great hiatus in the ascending sequence of formations, before we meet with the first trace of life in Peninsular India.

In most countries, again, great gaps, such as that just alluded to, occur in the succession of stratified rocks. These breaks in the geological record are most surely indicated by a more or less complete change in the fossil contents of the deposits above and below them. The names

of the main divisions in the geological scale of formations—the palæozoic, mesozoic, and cænozoic—originated in this way. But very generally these stratigraphical horizons are also well defined by a strong contrast in the arrangement and distribution of the preceding and succeeding strata, constituting what is called *unconformity* of the deposits so related. There is a most marked relation of this kind between the fossiliferous and the azoic formations in India. The unconformity is so complete that the oldest beds of the upper series occur nowhere in contact with the younger members of the lower, thus showing that a total change in the physical geography of the region was effected in the interval between the two, and that the duration of that interval must have been great. Unfortunately, the want of fossils in the lower series deprives us of all such means of comparing them with the rocks of other countries as would enable us to determine the magnitude of the break by the scale usually employed; a scale of which the divisions are marked by a known succession of organisms.

Several of the upper groups of the azoic series, of great thickness, and covering immense areas, are quite undisturbed and chemically unaltered; so there is no ground for supposing that their fossils have been obliterated. They comprise, moreover, a great variety of rocks—sandstones, shales, and limestones—and many phases of deposition, thick and thin layers, often with beautifully defined ripple, and rain-markings. As yet, however, they have yielded no fossils, although very large areas have been closely searched. We are to this day ignorant whether the highest of our azoic rocks, the Vindhyan series, are contemporaneous with any fossiliferous palæozoic group, or whether they are older than all rocks in which organic remains have hitherto been found. It is one of the puzzles and disappointments of Indian geology, for we must believe that the discovery will some day be made. This faith is not solely based upon the inference already stated, that life upon the globe was immensely antecedent to the oldest known fossils; there are also positive facts to support it:—we cannot, indeed, assign a period for the lapse of time between the azoic and the first fossiliferous deposits of this region, but it is certain that the first fossil forms in these latter are already more than half-way up in the known scale of life-progression, the greater portion, if not the whole, of the palæozoic era being unrepresented by fossiliferous deposits; and we know, from instances elsewhere of barren rocks overlying fossiliferous strata, that unfossiliferous deposits have been locally formed while life was abundant on the earth. The explanation of such facts is still obscure, there being no trace, in these barren deposits in India, of any ingredient prejudicial to life.

From the facts mentioned, we may surmise that an indigenous school of geology in India would probably have held very strict doctrines upon an absolute abrupt commencement of life upon the globe.

Three-fold division of azoic rocks.—It is thus evident that the term *azoic* is applied here in a merely negative and provisional sense. The word affords, for the present, a convenient collective designation for an immense series of rocks, more or less related in sequence, which have to be described connectedly, and which are totally severed stratigraphically from all the later formations of this great geological region. The base of the azoic series is the gneiss, the top is the Vindhyan formation, and between the two there are several well marked groups, or series, of deposits, having a great aggregate thickness. Some of these have certain characters in common, even at great distances apart, suggesting their close equivalence in time. It would simplify classification and description to assume this identity, and to stamp them with a common name, but these trenchant devices only end in complicating matters, and making final adjustment more difficult. It will be better to speak of all these intermediate groups as the transition formations, distinguishing the several sub-divisions as belonging to particular areas, or basins, and noting the relations of resemblance and of difference between them. We have thus the following three great systems of azoic rocks in Peninsular India:—

3,—Vindhyan.
2,—Transition or submetamorphic.
1,—Gneissic or metamorphic.

The areas occupied by these three divisions of our primary rocks are very unequal. More than half of Peninsular India is taken up by the gneissic series; and the Deccan trap, a comparatively modern formation, which is the next most widely spread rock of this region, is probably throughout a large part of its extent underlaid by gneiss.

Three gneissic regions.—In spite of the numerous interesting problems presented by the metamorphic rocks of India, and although the area composed of these formations exceeds that of all other groups together, the study of the crystalline strata has necessarily been deferred by the Geological Survey until our knowledge of the newer formations is more advanced; and consequently we still know but little of the former except in the neighbourhood of the latter. It is presumable that, within the immense area of crystalline rocks exposed in India, there are, as elsewhere, metamorphic representatives of several groups of strata of different geological age; but we can at present only indicate three sub-divisions which have more than superficial value. These sub-divisions

are probably to some degree distinct in geological age, and they occupy three distinct areas of very unequal extent.

Main or Eastern area.—With the exception of a narrow strip of overlying strata in the basin of the Godávari, connecting the eastern sea-board with the spread of the Deccan trap, gneissic rocks extend without a break from Cape Comorin to Colgong on the Ganges, at the north-east corner of the rock-area of the Peninsula. The distance in a straight line is 1,400 miles, and the mean breadth of this gneissic tract is about 350. This immense expanse of ground, with a few inliers exposed by the removal of covering strata in midland India, must form one of the divisions indicated, the interruptions to continuity being only superficial. For the same reason we must place in this natural group the gneissic rocks forming the basis of the Shillong plateau and Lower Assam. Although separated from the Peninsula by a gap of 150 miles, through which the Ganges and Bráhmaputra pour their waters, this now isolated mass undoubtedly belongs to the original *terra firma* to which the later mountain-systems of the Himalaya and of Burma have since been added. It is, moreover, recognisably related to the main gneissic area of Hindustan.

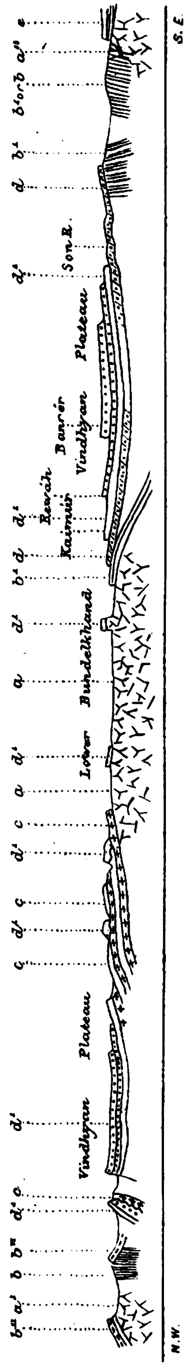
The interruptions to this main gneissic area are only superficial, and consist of patches of much younger strata resting upon, or faulted into, the fundamental rock. It is otherwise with the separation between the main area and the gneiss of Bundelkhand. This break is connected with one of the leading structural characters of the region, one that still affects the features of the country in a very marked way, but that dates from the azoic period, and in which the gneiss itself took part. The zone of separation is about 90 miles wide; and it is here that we find the fullest section of the upper azoic series, both transition and Vindhyan. A band of schists, slates, and quartzites fringes the main gneissic area on the north, and extends in a steady west-south-west direction from Manghir (Monghyr), near the north-east extremity of the gneiss in Bengal, at first along the south margin of the alluvial plains of the Ganges, then up the Son (Soane) valley, whence it crosses continuously into the Narbada (Nerbudda) valley, and down the latter to Barwai (Burwye), where the basaltic formation stretches across between the Deccan and Malwa plateaux. From the Gangetic plains to the spot where they disappear beneath the Deccan traps, the transition rocks are in contact on the north with the Vindhyan formation of the Bundelkhand and Malwa plateaux.

On the extension of the same line to the east-north-east we find a corresponding band of schists and quartzites, similarly related to the gneiss of the Shillong plateau.

Bundelkhand area.—To the north of the Vindhyan plateau in Bundelkhand, there is a compact semi-circular area of gneiss. On the north-north-east face, for 200 miles, along the chord of the arc, the gneiss is gradually overspread by the Gangetic alluvium, and round the convex southern margin, the metamorphic tract is bounded by a scarp of Vindhyan sandstones. At many points along the south-east side of the arc, there are narrow outcrops of the transition formations, recognisably the same as those of the Son and Narbada valleys. We thus have the means of comparing the relations of the gneissic rocks of the two areas, and the result is very significant. Formations that rest undisturbed, unaltered, and almost horizontal on a denuded surface of the Bundelkhand gneiss, are uniformly disturbed, metamorphosed, and subject to granitic intrusion in the gneissic region of the main crystalline area. This is almost conclusive evidence that some, at least, of the latter is of later date than the gneiss of Bundelkhand, which will therefore take precedence in order of description as the oldest known rock of India.

Arvali area.—In the north-western quarter of Peninsular India there is a third independent area of crystalline and transition rocks. The Arvali (Aravulli) ranges are formed of them, and their name may be conveniently used to designate this geological region. To the south-west it extends into Guzerat, and to the north-east the ranges reach as far as Delhi. It is separated from the Bundelkhand area by 70 miles of Vindhyan rocks, which stretch up to near Agra, and form a broad structural barrier like that to the south-east. Here, too, some of the lower formations can be identified on both sides of the barrier, but the base-rocks are badly exposed, and the ground has been but very partially examined. In one or two spots near Alwar (Ulwur) a fundamental gneiss seems to be unconformably covered by the schists and quartzites of the Arvali system; but these latter have not been identified with the transition groups of Bundelkhand; so there is no clue as yet to the relative ages of the two gneissic groups of Arvali and Bundelkhand.

The separation of the Arvali crystalline region from that of Eastern India is not so distinct. Only 50 miles of a covering formation (the Deccan trap) intervenes between the schists already mentioned as seen in the Narbada valley near Barwai, and the extreme eastern inliers of the Arvali crystallines about Bágh. The rocks in both positions are, moreover, very similar in composition and metamorphic condition, but it has been observed that a different direction of the structural features (cleavage and foliation) obtains in the western area. This is an important character in the discussion of highly disturbed formations, and shows that the distinction of the two regions is not purely superficial, arbitrary,



Diagrammatic section from Alwar to South Rewah.

a'', Gneiss, Bengal. a', " Arvali. a, " Bundelkhand. b'' Lower Transition, Arvali. b', " Bijáwar. b, " Slates. c, Upper Transition, Gwalior. d', Upper } Vindhyans. d, Lower } Vindhyans. e, Gondwana.

or geographical. It is, moreover, evident that the main basin of transition rocks, if extended to the south-west beneath the overlying trap, must intervene between the Arvali and the south-eastern gneissic regions.

A key section.—Before noticing the few particulars known regarding each area and the several members of the azoic series, it will be well to get a general idea of their relations by a brief discussion of a diagrammatic section taken in a north-west to south-east direction across the Bundelkhand gneiss, and prolonged as far as the eastern gneissic area on one side and to the Arvali gneiss on the other (see figure). All the features represented are not found on a single straight line, but each is taken from the zone in which it appears on the section. The distance is about 350 miles, and the figure is, of course, very much distorted, but it will afford assistance in understanding the features.

Three distinct formations are found in contact with the Bundelkhand gneiss along its south-eastern margin. The lowest is well seen in the Bijáwar State, and it was first described under the name of Bijáwar.[1] Its relation to the fundamental rock is locally very clear: its bottom beds rest flatly upon an irregularly denuded surface of the gneiss, and mantle round the anciently weathered outcrops of the quartz-reefs which traverse the latter. Thus, the break between the gneiss and Bijáwars is

[1] Mem., G. S. I., Vol. II, pp. 6-35.

total. The latter formation thickens rapidly to the south-east, and the beds in this direction exhibit considerable disturbance and some metamorphism. The Bijáwars are overlaid by very different strata, which have been locally described as the Semri group, from the river of this name, in which they are well exposed.[1] They, too, thicken to the south-east and have been moderately disturbed, but show no sign of metamorphism. In places they quite overlap the Bijáwars and rest directly on the gneiss. It would seem that this extinction of the Bijáwars is, at least to some degree, an original thinning out, and that they never extended indefinitely over the crystalline area. In their turn the Semris are overlaid and over-lapped by the Vindhyan formation, outliers of which cap hills of gneiss beyond the margin of the sedimentary basin.

On crossing to the south-east of the Vindhyan plateau, we find some important changes in the relations of the underlying rocks. The equivalents of the Semri beds are fully identified in the Son (Soane) valley. Here, again, there is no contact-unconformity between them and the Vindhyans, but there is the most complete break possible between them and an underlying series, part of which, at least, corresponds with the Bijáwar beds. Intrusive granitic masses are found in the Bijáwars, but do not penetrate the bottom beds of the Son series, which not only repose horizontally on denuded surfaces of both the Bijáwars and the granite, but extend in places on to the gneiss of the eastern region. These features imply a break of immense duration between the Son and the Bijáwar series, and establish on this horizon a main division in our azoic system. The other important contrast between the sections in the Son valley and in Bundelkhand is, locally at least, the complete metamorphic transition between the Bijáwars and the gneiss. They must have together undergone disturbance and metamorphism. If, then, we are correct in taking the transition rocks of the two localities to be Bijáwars, on the same geological horizon, this contrast of conditions involves a much younger age for the Bengal gneiss, or for some portions of it.

From the section sketched in the last paragraph we obtain the main outline of our azoic series: gneiss of two ages, a transition formation, and a well separated upper series. It will be convenient to speak of the Semri and Son deposits as Lower Vindhyans; for, although by no means co-extensive with the Vindhyans proper, even in this basin, they are everywhere conformable to them throughout a very extensive area.

By continuing the section to the north-west, we are able somewhat to expand the general series. All round the western edge of the Bundelkhand gneiss the upper Vindhyans are the covering rock, but at the

[1] Mem., G. S. I., Vol. II, p. 6.

north-west corner of the crystalline area a new formation crops out to the eastward from beneath the Vindhyans, and forms a north boundary to the gneiss. This, which is known as the Gwalior formation, is unconformable both to the gneiss and the Vindhyans; it rests at a gentle inclination upon the former, and its surface has been deeply eroded before the deposition of the latter, the bottom beds of which are largely made up of Gwalior debris. The Gwaliors have undergone but little disturbance and no crystalline metamorphism.

Judging from the presumptions afforded by these stratigraphical features, we have here a formation intermediate between the lower Vindhyans and the Bijáwars, a representative of the great break which has been shewn to exist between these two series in the Son region. The lithological characters would support this conjecture, which is further borne out by the fact that far away in Southern India we find a formation (the Karnul) resembling the lower Vindhyans and resting unconformably upon another group (the Kadapah) which has a great resemblance to the Gwaliors, and which there, too, is quite unconnected with the gneiss. If we might adopt total severance from the gneiss as a criterion in our main classification, it would be better to bring the Gwaliors and their equivalents into our general nomenclature as lower Vindhyans, and to convert those now so designated into middle Vindhyans (or to introduce some new class-name in this sense); but it is safer for the present to postpone any attempt at a permanent classification, and so we may let the Gwaliors and their allies stand in our scale as upper transition groups.

After crossing the northern arm of the great Vindhyan basin in a north-west direction from Gwalior, the change to the Arvali region is abrupt. The boundary is mostly faulted, the horizontal beds of the upper Vindhyans abutting against the fault, close beyond which a few outliers occur of Vindhyan rocks, and with some of them Gwaliors are associated, both being more or less vertical. Away from the boundary (to the westward) we only find formations of a different type, which have been described as the Arvali series. They are greatly disturbed and altered, and their relation to the underlying rocks is very puzzling. Locally they rest abruptly upon a massive granitoid gneiss;[1] elsewhere they are associated at the base with an arkose or pseudo-gneissic rock which is locally difficult to distinguish from the true gneiss.

These are difficulties for which we shall have to notice a parallel in the Bijáwar area itself and in Behár, so the Arvali rocks may probably be ranked with the lower transition groups as already defined. But a further

[1] It is doubtful whether some of this is not intrusive granite.

difficulty meets us: in the same region these Arvali strata rest upon the edges of a schistose slate formation (see section) which must, of course, be an older member of the transition series. The ground in which these rocks occur has, however, been so little examined, that any views now expressed must be considered as open to much correction.

General composition and distribution of azoic rocks.—It is only in the most general way that any common characters can be established amongst rock-groups so widely scattered, so doubtfully affiliated, and so little studied.

The following general classification will show the plan to be followed in describing the various sub-divisions. Like all such tabular arrangements in the present work, the formations are grouped in descending order, but in describing them it will be more convenient to commence with the lower groups:—

III—VINDHYAN	*Upper*	Comprising in descending order the Bhánrer (Bundair), Rewah, and Kaimúr (Kymore) groups. Sandstones and shales greatly predominate, whilst limestone occurs as a subordinate member in the upper group. Only known in the great northern basin, extending from Sasseram to Nimach (Neemuch) and Agra.
	Lower	Son, Semri, Bhima, and Karnul groups, all more or less equivalent to each other. Limestones, sandstones, and shales are generally distributed. Found in several basins, the principal of which, commencing at the north, are (1) the great northern or Vindhyan basin, on both sides of which lower Vindhyans crop out; (2) the Chhattísgarh area, extending south to Bastar, in proximity with several scattered tracts in the valleys of the Pem, Pranhíta, and Godávari rivers; (3) the Bhima; and (4) the Karnul basins.
II—TRANSITION or SUB-METAMORPHIC	*Upper*	Gwalior, Kadapah, and Kaladgi representative groups. Quartzites or sandstones, slates or shales, with limestone, jasper or iron bands and interbedded trap. The principal basins are those of (1) Gwalior, (2) Kadapah, and (3) Kaladgi.
	Lower	Arvali, Bijáwar, Champanir, and Maláni groups. Slates, more or less schistose, and quartzites in about equal proportions, with locally associated limestone and contemporaneous trap. The Maláni group is volcanic. There are two principal regions, (1) the Arvali, and (2) the interrupted areas in the Narbada and Son valleys, Bundelkhand and Behár, with detached area in north-east Bengal, all of which must be described as parts of the same tract. There is also a large area of these rocks in south-west Bengal, besides some minor exposures, which cannot even be indicated on the map.
I—GNEISSIC or METAMORPHIC		Three sub-divisions, Arvali, main or eastern area, and Bundelkhand, the latter being older than the others. Gneiss, schist, and other forms of crystalline metamorphic rocks with intrusive granitic veins. The regions correspond to the sub-divisions.

Bundelkhand gneiss.—The gneiss of Bundelkhand takes precedence in order of description, being the oldest, so far as now known, in India. It forms the basis of lower Bundelkhand as distinguished from the higher portions of that district lying on the adjoining Vindhyan plateau. On the north-north-east border, for 200 miles, the gneiss is gradually covered by the superficial deposits forming outlying and marginal portions of the Gangetic plains, at an elevation of 500 to 600 feet above the sea. Elsewhere the area is very sharply bounded by a scarp of overlying formations, whether Vindhyan or transition. Along the base of the scarp to the south-west the elevation varies between 1,000 and 1,200 feet above the sea, the scarp itself rising to 1,900. The gneiss sometimes forms hills, but the general features of the ground are flat, undulating uplands, sparsely cultivated, including shallow valleys and plains of alluvial land. All over lower Bundelkhand long narrow serrated ridges composed of quartz-reefs form a most striking feature of the landscape. They run in straight lines, generally with a north-east to south-west direction, and sometimes attain an elevation of 600 feet over the surrounding country.

Composition of the gniess.—Gneiss is by far the commonest rock.[1] It may be described as consisting of some six minerals—red orthoclase felspar, a white plagioclastic (triclinic) felspar (probably oligoclase), quartz, hornblende, chlorite, and mica. In any one place the gneiss may contain only two of these, or it may include all of them. With regard to texture, every variety is met with, from a homogeneous felstone, in which no individual mineral can be distinguished, even with a lens, to a coarsely porphyritic rock, including felspar crystals more than two inches long. The orthoclase nearly always forms the main mass, and exceeds in quantity all the other minerals together. Its ordinary colour is a darkish red, but now and then it is much paler, and almost or quite white. In such cases, when both felspars occur, it is not easy to distinguish them on a fresh fracture, but the difference becomes apparent on a weathered surface. One (the orthoclase) has a vitreous, or somewhat pearly, lustre and translucent aspect; the other is dull and quite opaque, having been superficially altered into kaolin. The plagioclastic felspar is a comparatively uncommon mineral; when present, it plays quite a subordinate part, and occurs in much smaller crystals than the orthoclase. As often as not, no free quartz can be detected in the gneiss, and it very rarely indeed occurs in large quantity. The rock is usually hornblendic, but sometimes the hornblende is partially or entirely replaced by chlorite

[1] The characters of the rocks of this area are chiefly taken from the unpublished reports of Mr. F. R. Mallet.

and mica. The mica occurs of varying colours and of more than one species, both uniaxial and biaxial—green, brown, black, and silvery-white, the last being rare, and chiefly found in the southern part of the area.[1]

Foliation is seldom well developed, the rock being very commonly to all appearance perfect granite. No direct evidence has, however, been obtained beyond this, of the existence of true plutonic granite; and sometimes by close examination traces of foliation may be detected in

[1] The mode of grouping of these minerals will be best illustrated by a few particular examples of the common and the rare kinds. The ingredients are generally mentioned in the order of their prominence in the compound.

The hill at Pahári (10 miles north-north-east of Kirwi (Kirwee), is of coarse red-felspar-gneiss, with specks of dark-brown mica and a small proportion of quartz; through this rock small masses occur, from an inch to a foot in size, of a very fine-grained, more micaceous variety. The gneiss is intersected by a few seams of pegmatite, red felspar, and quartz, the felspar much preponderating. The gneiss, in which no foliation is traceable, covers the hill in large rounded blocks.

At Bambai (2 miles north-west of Kirwi) some of the gneiss is hornblendic, and in one place it is composed of red felspar, hornblende, and epidote. At Subhápur (10 miles south-west of Kirwi) the gneiss is hornblendic, passing into very fine-grained and compact hornblende-rock; a little south of this, true hornblende-schist occurs. At Dongáho (6 miles west of Ajigarh) the gneiss is of a common variety—a very large proportion of red felspar in coarse crystals with some hornblende, no quartz being apparent to the eye. Throughout this rock there occur bands of similar composition to the above, but extremely fine-grained.

Near Telorna (10 miles east of Chhatarpur) the gneiss is highly syenitic, with red felspar in the usual large proportion. At one spot it was observed to contain red orthoclase, white plagioclase, hornblende, black mica, and quartz.

At Páli (5 miles south-west of Nowgong) the gneiss consists of pink felspar in large crystals, green felspar in much smaller crystals, and chlorite.

Between Punon and Torea (7 miles east of Mohangarh) is a dark brownish-red felstone in which the minerals cannot be distinguished. At Deorat Ghât, Rámpura, and Kungirpura (5 miles south-west of Mohangarh) the gneiss consists of dark red felspar, quartz, and chlorite, the latter in small quantity. The rock is deep red from the felspar, but there is a considerable amount of quartz, in some specimens exceeding the felspar and chlorite together. In the Jamni river at Hirápur the gneiss is both fine-grained and coarse. Irregular seams and masses of each variety are included in the other, showing that both are the same rock.

The gneiss on the north-west side of Gunchári (12 miles east of Lalatpur) is moderately coarse, and includes no less than six minerals; orthoclase, white felspar, quartz, black mica, chlorite, and hornblende. It is the only place in which so complex a mixture has been observed. In the stream just south of Sindwána (16 miles south-east of Lalatpur) the rock is composed almost wholly of white felspar (orthoclase?) and quartz. The rock between Ikona (5 miles east of Maraura) and Girai is nearly all white orthoclase, frequently with silvery mica. At Bikrampur (16 miles north-north-east of Tehri) and elsewhere, a variety of gneiss is found, consisting of large crystals of red orthoclase, their longer axes preserving a general parallelism, imbedded in a matrix of impure chlorite, probably an impalpable mixture of chlorite and quartz. About Shágarh the rock is close-grained and granitic, with felspar, both red and white, black and silvery white mica, the latter being specially prominent in the pegmatite veins.

rock which at first sight appears quite devoid of it. This foliation generally has an east-north-east direction, but varies to north-east and east-south-east. The planes are more or less vertical.

The schists.—The subordinate varieties of rock, all combined, are of very insignificant extent in comparison to the gneiss. One of the most prominent is hornblende rock. At Jumúni (16 miles east-north-east of Tehri) there is a band about 50 yards wide of almost pure hornblende, showing cleavage-faces of an inch to an inch and a half long. It contains a small amount of epidote, and also white felspar, the latter disposed in irregular seams, more or less connected with the foliation, which is obscurely seen. A similar rock occurs in the Sujnám stream, west of Sokári (15 miles east-south-east of Lalatpur), and again north-west of Barwar, on the Lalatpur-Chandéri road. Another well marked variety contains about equal quantities of hornblende and white or greenish-white felspar in crystals about an eighth of an inch long. It may be seen east and north-east of Bánsi (10 miles north-by-east of Lalatpur). This rock sometimes contains, in addition, an inconsiderable proportion of reddish felspar, quartz, and green mica, and very minute specks of iron pyrites. The hornblende-rock sometimes resembles trap very closely; parts of it are as fine-grained as the intrusive dykes of diorite or the overflowing basaltic trap, and it weathers into similarly rounded lumps; but this variety passes into a much coarser kind, in which the felspar and quartz are well separated. The most trappean-looking portions, moreover, contain thin strings and films of epidote, which have not been observed in the trap.

Besides the hornblende-rock, various forms of schist occur with the gneiss, comprising talcose, hornblendic, chloritic, quartzose and even argillaceous schist, and the combinations of these with each other. Mica schist has not been observed. Schists are of very rare occurrence in the gneiss generally, but all the above varieties are to be found in some force in the southernmost part of the area, in the Maraura region. This peculiarity of distribution is so marked that it was thought that the schistose strata might here be separable from the gneiss. The suggestion is much encouraged by the fact that the great quartz-reefs, elsewhere so prevalent in the gneiss, stop short of this ground. It has not, however, as yet been found possible to draw a line between the gneissic and the schistose sub-divisions. Gneiss of the usual type is still a prevalent rock in the schistose area, and is the most southerly rock seen at Sháhgarh. It seems, too, to be truly associated with the schists. We may perhaps at least infer that in this region we have the top of the gneissic series of Bundelkhand.

The only stratigraphical feature observable in the gneiss of Bundelkhand is near the Dhasán river, in the southern part of the area, and consists of a synclinal fold, about two miles wide, marked by the recurring outcrop of a very conspicuous, banded, iron and quartz rock, dipping north at Baréta and south at Barwar; at Gerár, on the same strike as the last-named, the rock is inverted. Signs of an obscure outcrop of the same rock were noticed some ten miles to the north; and again, the iron-ore worked at Dháowára, ten miles south of Orchha, is this banded rock. It is composed of thin alternate laminæ of hæmatite and quartz; the former has a metallic lustre, although more or less silicious; the quartz is red and white, some laminæ being jaspery, others somewhat arenaceous, with distinctly visible grains, the latter form being probably decomposed. This is a type of rock of frequent occurrence in different formations of the azoic series—in the gneiss of Southern India, and in several of the transition groups.

It is a noteworthy fact that over the whole of this large area of gneiss not a single bed of limestone has been detected.

Granitic veins.—Pegmatite veins, from a few inches to a foot or two in breadth, are very common. If these were intrusive, it might be expected that they would be somewhat uniform in composition irrespective of the nature of the surrounding rock; but it has been invariably observed that the felspar of the vein is the same as that of the rock adjacent, whether the latter is orthoclase or plagioclase, or includes both; the chief difference consists in the larger crystallization and in the usual absence of the third mineral (hornblende, etc.) in the veins. It is therefore presumable that the veins were formed by segregation at the time of the crystallization of the gneiss.

The almost total absence of accessory minerals in these rocks is remarkable.

Quartz-reefs.—The quartz-reefs, already mentioned as forming a conspicuous feature of this area, are exclusively confined to the gneissic series. They are pretty equally distributed over the ground, with the exception noticed in the southern region, which, moreover, lies right across the strike of the reefs to the north-east.

Out of 110 local observations (principally taken in the eastern region), many being of different parts of the same reefs, Mr. Mallet found that 76 had a strike between 20° and 80° east of north, their mean direction being north-36°-east. In some minor cases the strike is more north-north-west. Instances of bifurcation are occasionally seen. Sometimes the same reef is very unsteady; that at Mulgoah (20 miles south-by-east of Nowgong) twists from north-35°-east to north-5°-west.

The vein at Mau (Mow) (near Nowgong) is double, or rather two veins run parallel at about 100 yards apart; just south of the town they are thrown about 300 yards horizontally by a fault running west-20°-north. The breadth of the veins varies from a few feet up to 100 yards; the latter dimension was found by rough measurement in the reef west of Bagwa (20 miles east-south-east of Tehri). Some of them are traceable in a direct line for more than 60 miles, the local interruptions which occur being sometimes due to removal by denudation, sometimes to strangulation of the vein itself. Other reefs, again, though of full thickness and very prominent at the surface, are short, and end abruptly. There is a good case of this at Dehri (12 miles south-east of Tehri) where a broad reef, 300 feet high, is only about a mile long, no trace of it occurring in the gneiss to the north or south. The narrow gaps by which the minor streams in many places cross the reefs give peculiar facility for the formation of lakes, as a very short dam is often sufficient to pond back a large surface of water: many of the numerous artificial lakes in Bundelkhand are formed in this way.

The reefs are often affected by joint-planes, which sometimes give an appearance of horizontal bedding to the mass. When parallel with the direction of the reef itself, they suggest in a more puzzling manner the impression of a bedded mass. Now and then the quartz is much shattered. At Deokalli (20 miles east-north-east of Chhatarpur) and Bagpura (25 miles south-east of Tehri) samples might be taken for the Bijáwar hornstone-breccia, a description of which will be found on a subsequent page.

Owing to the metamorphic condition of the reefs themselves, foliation is often developed; and it usually extends to the contiguous gneiss, which is generally so amorphous. When the foliation in both rocks has the same direction as the reef itself, as is the case at Chetrai (5 miles south-east of Rájnagar) the quartz mass might be taken to be interbedded with the gneiss. Generally the foliation is oblique to the direction of the vein, while still the same as that of the gneiss.

Many of the reefs are of greyish white quartz. Frequently they contain a large amount of impure serpentine, and occasionally they are formed almost entirely of this material. The more northerly of the two ridges at Dallipur (10 miles north of Sháhgarh) is an example. At Rájápur (8 miles west-by-south of Kálinjar) a band of nearly black serpentine occurs, apparently a continuation of the quartz vein to the north. In many cases the gneiss is serpentinous for some distance on each side of a vein, there being no distinct separation between the two rocks. North of Patauri (25 miles east of Tehri) the gneiss near a quartz

vein is composed of red felspar, quartz, and serpentine. Serpentinuos gneiss has not been observed, except near a quartz vein. Steatite takes the place of serpentine in a few veins. At Kudunwára (20 miles south-south-east of Orchha) the rock consists chiefly of this mineral. Some of the steatite is pure and has been quarried. On the flank of a ridge south-west of Sikana (20 miles east-south-east of Tehri) a large mass of steatite is extensively worked.

From his observations, as above sketched, Mr. Mallet concludes that the reefs were probably formed before the metamorphism of the gneiss was accomplished.

Many of the quartz-reefs as well as the gneiss itself are traversed by more recent and much smaller veins of pure white quartz, the thickest not much exceeding one foot in breadth. They are very frequently crystalline and drusy in the centre, and they are always sharply distinct from the rocks they traverse. Their direction is very irregular.

Trap dykes.—The gneiss of Bundelkhand is also remarkable for being traversed by extensive trappean intrusions, none of which penetrate any of the younger formations. These dykes, of true igneous rock, are more numerous than the quartz-reefs, and exhibit nearly as much regularity in their course, their prevailing direction being about north-35°-west, so as to cut the reefs obliquely at an angle of about 70°. Some few run east of north, and due east. Many are of considerable size, a breadth of 100 feet being not unfrequent; some are much wider. They are often persistent for great distances. The commonest type is an extremely hard and tough close-grained greenstone (diorite), in which the hornblende and the white felspar are sometimes clearly separated. The rock often weathers into large rounded blocks without any tendency to exfoliation. The small dykes are of a more earthy texture.

It is very rare to find any intersections of the dykes and reefs that can be taken as conclusive of their relative age. It is not so uncommon to find a dyke running close up to a reef on both sides without cutting it; but such an occurrence might easily happen, although the reef were the older, as it may have offered a greater resistance to splitting. One good case of the converse carries much more weight. Mr. Mallet records such an occurrence at about half a mile west-south-west of Bhagwáho, where a quartz vein striking east-20°-north abuts against a strong dyke running west-20°-north, traces of the quartz being found also on the other side. But he considers the general argument from the condition of the two rocks to be independently conclusive: the trap has certainly not undergone metamorphism, whereas the reefs as certainly have.

Accessory minerals.—The great rarity of accessory minerals in these rocks has already been noticed. Mr. Mallet only mentions epidote sparingly in the hornblende rock; schorl in some of the small quartz veins of the Maraura region, small grains of ilmenite in some of the pegmatite veins, and strings of altered kyanite in the quartzose rock of Dhánkua hill (10 miles west-north-west from Tehri). Small pieces of galena have been sent from Jhánsi for analysis, but their locality is not known, and they may not have been procured from the gneiss. Iron ore has been extensively burrowed for at Dháowára, 10 miles south of Orchha; it is a decomposed earthy condition of the banded hæmatite and quartz. The absence of any trace or tradition of gold in connection with the quartz reefs is noteworthy. The steatitic rocks are quarried to be turned into plates and bowls; and a talcose quartz schist of the Maraura region is much used for quern-stones (handmills). The coarse porphyritic granitoid gneiss is a favourite stone for the pillar sugar-mills. The massive gneiss would make fine building stone, but it is only used as rubble; the natives mostly build their houses of brick, using the Vindhyan sandstone for more important edifices.

Contiguous formations.—The history of this comparatively small area of gneiss would be very interesting. It has served as a shore or a bed for each of the great adjoining formations. The Bijáwars and the Gwaliors lie upon its margin north and south, but no detached outliers of either are found within its border, so that it may have been a well elevated area at the period of their formation. The same may be said of the lower Vindhyan deposits. It is not so with the upper Vindhyans, of which the outliers are numerous and lie at considerable distances from the scarp of the basin. In the east these form a portion of an ascending slope, the base of the capping Vindhyan sandstone being higher in the outliers than in the scarp. But in the north-west it is curiously the reverse; the gneiss reaches high up all along the western scarp, but the outliers of Vindhyan sandstone to the eastward rest at the general level of the low country.

The next overlying formation is the Deccan trap, remnants of which are found on the low ground in the southernmost part of the area, and traces of the infra-trappean (Lameta) conglomerate occur more extensively in the same position. That this portion of the scarp-bounded area can have been so occupied, almost necessarily implies that the whole of the gneissic ground must, at the period of the Deccan trap, have had a configuration very like what it has now; and, the source of the eruptive rock being presumably to the south or south-west, the lava must have poured from the plateau to the low lands. In the Madanpur gorge

trap does, in fact, occur continuously from one level to the other, but its condition suggests no resemblance to a lava stream.

The main gneissic region.—The great gneissic area of Eastern India cannot now be described in any detail. Its limits will be best understood by an inspection of the map. Along its north-north-west margin the gneiss is intimately connected with the transition series. Their detailed boundary is very intricate, and the general relation of the two formations is obscure, although some individual sections are simple enough. The discussion of the relations between the gneiss and transition rocks must be deferred until the latter have been described, as it is impossible to enter into details without referring to the character of the upper series. The same plan of describing the relations between the groups when treating of the highest will be adopted in other cases also.

At the east end of the northern boundary the schists appear as detached and semi-detached ridges, the Gangetic alluvial plain reaching at many points up to the main gneissic area. In the small valleys draining northwards from the crystalline plateau, remnants are found of the bottom Gondwána deposits, showing to how great an extent the actual features of the metamorphic rock-mass are a reproduction of a very ancient surface; for it is certain that, in the interval between the lower Gondwána period and the present day, the superficial characters must have been very different from what they are now. Along the whole north-east border, for 80 miles, the Bengal gneiss passes under the Gondwána strata of the Rájmehál hills, not altogether owing to a general tilt of the surface, but partly to an original slope, for the successive groups of the series overlap each other on to the gneiss.

These hills being the most north-easterly point of the peninsular rock-area, it would seem as if the isolation of the gneiss of Lower Assam and the Shillong plateau might date from the Gondwána period; but against such a supposition there are objections that will be discussed elsewhere. Facts analogous to that just noticed in the Rájmehál hills occur at intervals along the whole east coast of the peninsula: the description of them belongs to the section of this work relating to the Gondwána system.

Little is known of the Malabár coast. The gneiss is probably nowhere far from the surface. From Malwán northwards it is replaced by the Deccan trap.

The north-west boundary of the main gneissic area, passing obliquely across the peninsula, is exceedingly tortuous, the metamorphic rocks being exposed wherever the various overlying deposits, the upper transition

rocks, the lower Vindhyans, the Gondwánas, and the Deccan trap have been removed by denudation. As the nature of the junction with the gneiss will necessarily be described in connection with each of these formations, it need not be repeated here.

The present surface-configuration of the gneiss is very varied, and altogether assignable to denudation. On the Bengal side there is the upland or plateau of Hazáribágh and Chutia Nágpur, much of which has an elevation of 2,000 feet, scattered hills ranging up to 4,000. The high-level gneissic mass beneath the Deccan trap on the Mandla plateau, and extending eastwards to Sirgúja, and westwards through Chindwára and Betúl, may have some structural affinity with the highland of Chutia Nágpur, the general east-north-east and west-south-west strike of the strata being common to both areas.

At a short distance from the coast, between the Máhánadi and the Godávari, the highlands of Jaipur form an independent watershed of gneissic rocks. A basin of Lower Vindhyans bounds this highland on the north-west; on the north-east a broken chain of Gondwána outliers in the Máhánadi valley separate it from the Chutia Nágpur plateau, and the continuous basin of these deposits in the Godávari valley separates it from the Hyderábád plateau on the south-west.

The gneissic plateau of Hyderábád, between the Godávari and the Krishna, has only an elevation of about 1,100 feet. It is in the south of the peninsula that the gneiss attains its greatest prominence, in the plateau of Maisur and the Nilgiris, culminating in the peak of Dodabetta, 8,760 feet high. The Pálghát gap separates the Nilgiris from other lofty clusters of gneissic hills, the Palne and Anámale, in Trávancore.

The main gneissic area is so extensive, and many parts of it are so little known geologically, that it is impossible to give a general description of its characters, and it is better, when noticing the more important peculiarities of the rocks, to treat separately of those portions of the region which have received special notice, and concerning which any details of importance have been recorded. The following are the tracts, included in the main area, of which some information is recorded, beyond the mere occurrence of metamorphic rocks:—

1.—Bengal area.
2.—Singhbhúm.
3.—Orissa.
4.—Central Provinces.
5.—South Máhratta area.
6.—Southern Konkan.
7.—Wainád.
8.—Nilgiri Hills.
9.—Trichinopoli and Arcot.
10.—Assam.

The Bengal area (including Bhágalpur, Birbhúm, Hazáribágh, Chutia Nágpur (Chota Nagpore), Mirzapur, Rewah, and Sirgúja).—

The probability of a difference in age between the gneiss of Bundelkhand and that of Bengal has already been suggested, the suggestions being chiefly founded on the different stratigraphical relations between the gneiss of each area and the Bijáwar formation. In connexion with this question it is fortunate that the best information we possess regarding the characters of the rocks of the main gneissic region refers to the ground contiguous to the Bijáwar basin, in Rewah, Mirzapur, and Behár. There is the further advantage that Mr. Mallet is again our authority, so that we have not to allow for discrepancies of observation.[1] He gives the following tabular abstract of the constituents of the gneiss in Singrauli, a petty principality now absorbed in the Rewah State and adjoining districts:—

1.—Minerals occurring as constituents of the gneiss:—
  Quartz; orthoclase; oligoclase; muscovite; biotite; hornblende; epidote.

2.—Occurring in beds in the gneiss:—
  Limestone; dolomite; corundum; magnetite; quartz as quartzite and quartz-schist; hornblende as hornblende-rock, tremolite-rock and jade; mica as mica-schist; epidote.

3.—Occurring in veins in the gneiss:—
  a.—Quartz in veins and reef-quartz.
  b.—In pegmatite veins (as constituents): orthoclase; oligoclase; quartz; mica.
  c.—In epidotic veins: epidote; quartz.

4.—Accidental minerals in the gneiss:—
  Magnetite; ilmenite; schorl; garnet; stilbite (?).

5.—Accidental minerals occurring in the subordinate beds (2) of the gneiss:—
  a.—In the limestone: magnetite; pyrite; hæmatite; serpentine; chrysotile; phlogopite(?); wollastonite.
  b.—In corundum bed: schorl; euphyllite; diaspore.
  c.—In jade bed (associated with corundum): corundum; rutile (?); schorl; euphyllite.

6.—Accidental minerals occurring in the veins, &c., in the gneiss:—
  a.—In the quartz-veins: micaceous iron; tremolite; augite; epidote; schorl; muscovite.
  b.—In the quartz-reefs: galena; cerusite.
  c.—In the pegmatite veins: schorl; garnet.

To this list may be added the minerals found by Mr. Mallet in the same zone, further to the east, in Hazáribágh: lepidolite; tourmaline; beryl; apatite; leucopyrite; tin stone. Zircon is also said to occur.

The contrast between the minerals named in this table and the constituents of the Bundelkhand gneiss is very striking. The most marked differences are the abundance of the disseminated quartz, the

[1] Mr. Mallet's work has been only partially published: Rec., G. S. I., Vols. V, VI, VII.

comparative frequency of limestone and dolomite and of mica schist, and the general occurrence of accessory minerals in the Bengal gneiss. According to some current theories, by Dr. Sterry Hunt and others, on the chemistry of the primeval earth, this differentiation of the ingredients would be confirmatory of the opinion arrived at from stratigraphical considerations, that the Bengal gneiss, or part of it, is of later date than that of Bundelkhand.

The structural characters present another noteworthy point of contrast between these two gneissic series. In Bundelkhand the rock is generally homogeneous and amorphous, the foliation obscure and constantly in more or less vertical planes, as if due to the causes which produce cleavage. In the Bengal gneiss bordering the Bijáwar basin on the south, the foliation clearly coincides with the original lamination and bedding. These have a general east-north-east strike, corresponding with that of the main rock-boundaries, but the alternating strata fre quently roll about at low angles of dip, or are crushed together confusedly, the foliation constantly agreeing with the lie of the beds.

Quartz-reefs have been described in this gneiss also, but to a very subordinate extent, and their origin as veins is in many cases open to question. A common mode of occurrence of this quartz or quartzite is close to the boundary of the slate and gneiss series, but it does not coincide with their junction, and it is not in any sense a contact-formation, separating sharply distinct types of rock. It occurs in the strike of the foliation and stratification, and may well be an altered quartzite.

There is a rock common in this northern area of the Bengal gneiss, perhaps occurring most typically within the zone mainly occupied by the transition series. It is known as dome-gneiss, from its weathering into great hemispherical or ellipsoidal masses of bare rock, the only divisional planes being concentric layers of exfoliation. The domes are often several hundred feet high, and form a very peculiar object in a landscape. Foliation is always more or less traceable, and in every respect of texture and composition the rock is the same as that of thin bands alternating with schists in the adjoining ground. Both are often porphyritic, the dome-gneiss generally so, containing large ill-formed (rounded) crystals of felspar. There can be no doubt that the peculiar form exhibited by this rock is due to the occurrence of large masses of more homogeneous composition than usual, but the question is how these conditions were produced, whether we must not suppose a partial degree of plasticity to have been attained, and whether the rock is not in a manner intrusive. At the Kálapahár and the Bhiaura hills on the northern fringe of the

Hazáribágh plateau, and the Mandar hill of the Bhágalpur district in the same geological region, there are very typical examples of the dome-gneiss.

The comparative rareness of trap-dykes in the Bengal gneiss is another point of contrast with the Bundelkhand area. In some parts they are pretty frequent, perhaps most so in the vicinity of the basins of Gondwána rocks, and they are often continuous into such basins, their comparatively recent date being thus fully established; but they are by no means generally distributed.

Pegmatite is not uncommon in the gneiss of Singrauli. Mr. Mallet does not consider this formation to be intrusive; as was explained in the case of the pegmatite of Bundelkhand, its composition varies with the rock it traverses. In northern Hazáribágh, however, he describes the extensive occurrence of intrusive pegmatitic granite ramifying in the most intricate manner in veins and dykes of from half an inch to fifty yards wide, through both the gneiss and the transition schists, and maintaining its composition irrespective of the enclosing rock. It is composed, in order of crystallization, of tourmaline, mica, felspar, and quartz; all four being generally present, but their proportions vary greatly. Its texture is also very uneven, the coarsest forms being often found in comparatively narrow dykes. It is in this rock that the mica-mines of Behár are worked. Not unfrequently the pegmatite assumes the curious form known as graphic granite.

The gneiss of the Chutia Nágpur districts, up to the basin of transition rocks in South-West Bengal, is more or less freely interbedded with micaceous hornblendic and silicious schists, and occasional bands of the porphyritic granitoid variety. Patches also occur of less highly metamorphic schists. This division of the Bengal gneiss will again come under notice in connexion with the transition series.

Singhbhum area.—The junction of the Chutia Nágpur (Chota Nagpore) or Bengal gneiss with the transition rocks of Singbhúm (South-West Bengal) is described by Mr. Ball[1] as a great fault. But within this basin of submetamorphic rocks there are extensive inliers of a gneiss, apparently of an older date than that of Chutia Nágpur. It is very uniform and granitoid, and there is a total absence of the thin-bedded gneiss, schists, etc., which abound in the main gneissic area to the north. In contact with this Chutia Nágpur gneiss, the transition strata exhibit a minimum of alteration and disturbance. Mr. Ball describes them at and near Chaibássa as sandstones and mudstones resting immediately on the rough weathered surface of the granitic gneiss. There are local faults along the boundary, but it is certain that the original relation of the two series is like that

[1] Manuscript reports.

between the Bijáwars and the Bundelkhand gneiss, as already described. In the Singbhúm gneiss we again find a remarkable abundance of trap dykes, forming two intersecting systems having north-westerly and north-easterly courses, respectively.

Orissa area.—Further south, in the Tálchír country, the ordinary type of metamorphic rocks again prevails. The following rough classification of them is given by Mr. Blanford:[1]

Gneiss, *a.*—Hard, coarse, and felspathic, becoming sometimes lithologically a perfect granite.

„ *b.*—Soft, foliated, quartzose or micaceous.

„ *c.*—Compact, but sometimes soft, containing garnets, frequently decomposed,

Hornblendic gneiss or schist, soft and foliated.

Quartz-schist or schistose quartz, occurs frequently in bands separated by softer micaceous layers.

The variations in composition coincide with the planes of foliation, the prevailing direction being west-north-west to east-south-east.

Central Provinces.—Higher up the Máhánadi valley in the neighbourhood of Sambalpur, Mr. Ball[2] observed syenitic and protogenic gneiss as common, hornblende-rock and schist as somewhat rare, strong quartzites forming the most peculiar feature in the gneiss; mica-schist, quartz-schist, and shaly slate, and in one instance, near Kátikéla, north-east of Sambalpur, a conglomerate, were found associated with the gneiss. The strike in this region would seem to be very variable—east to west, north to south, north-west to south-east, and north-east to south-west, being all recorded.

On the same latitude, about Nágpur, Mr. Blanford[3] has noticed the general resemblance of the gneissic rocks to those of Bengal. Here, again, there is much irregularity in the strike.

South Mahratta area.—There is little or no information regarding the gneiss in Hyderábád, but for the adjoining South Máhratta country, Mr. Foote has given a sketch of the metamorphic rocks along the south border of the Deccan trap and of the Kaladgi and Bhima basins of transition and lower Vindhyan formations.[4] Massive syenitic and granitic forms of gneiss in great variety are the prevailing rocks, the schists being subordinate. Of the latter there are, in order of abundance, hornblendic, micaceous, chloritic, hæmatitic, and talcose schists. The two types of rock are not indiscriminately blended. The schists occur in definite

[1] Memoirs, G. S. I., Vol. I, p. 39.
[2] Manuscript report.
[3] Memoirs, G. S. I., Vol. ix, p. 301.
[4] Memoirs, G. S. I., Vol. xii.

bands, but their relation to the gneiss has not been clearly made out, or rather no separation into two series has been established. The relation would seem to be one of association rather than separation. The two run in parallel bands of varying width, having a general north-north-westerly direction, which is that of the main Sahyádri watershed. Mr. Foote indicates nine such alternating bands of gneiss and schist between Raichur and the crest of the ghâts. The gneissic bands are more rocky and prominent than those of the schists. They all pass southwards into Maisur (Mysore). The micaceous schists are most developed in the west, where they occur in force underlying the trap of the great scarp.

Crystalline limestone was observed in places associated with the schistose bands of the gneissic series in the South Máhratta country. The chief of these is the massive band of dolomite high on the western face of the Sahyádri range, at the extreme southern limit of the Deccan trap. The fort of Bhímgarh, east of Goa, is built on a mass of this dolomite.

Dykes of a dioritic trap are frequent in these gneissic rocks. Mr. Foote divides them into five groups, according to direction, but remarks that in every case of intersection the rock seemed perfectly confluent, as if both dykes had been simultaneously filled. This trap does not penetrate the overlying transition formations. Small veins of pegmatitic granite are of frequent occurrence in the Southern Máhratta country, but their intrusive origin is somewhat doubtful.

Some strong reefs of quartz occur in different parts of this region. They are mostly of pure white quartz, often in a brecciated condition, and re-cemented by vein-quartz or by some form of hæmatite. Their principal directions are north-west, north-east, and north.

The small auriferous tract of the Dambal or Kappatgudd hills is immediately south of the South Máhratta country, and the rock features described by Mr. Foote are very similar.[1] The gold-bearing reefs occur in a broad band of chloritic, hornblendic, argillaceous, and hæmatitic schists between two strong bands of granitoid gneiss, that on the east seeming to overlie the schists. The north-north-west strike still prevails. The most productive reefs also have this direction. The sources of all the streams said by the natives to be auriferous are within a tract of pseudo-diorite, which Mr. Foote does not consider to be irruptive, but a more developed metamorphic condition of the schists. Trap-dykes occur, but nothing special is noted of them.

Gneiss of the Southern Konkan.—The gneissic rocks of Sáwant-Wári and Ratnágiri, in the Konkan—the low country between the Sahyádri

[1] Records, G. S. I., Vol. vii.

range and the sea—would seem from Mr. Wilkinson's[1] description to be more varied than on the Deccan plateau above the ghâts. The distribution in separate bands of more massive and more schistose characters does not occur. The beds consist of true gneiss (*i. e.*, a well foliated quartzo-felspathic rock), micaceous and hornblendic schists, quartzites and altered micaceous sandstones, with some subordinate bands of granitic and syenitic gneiss, also occasional talcose, chloritic and actinolitic schists; limestone is only noticed near the foot of the Talewari ghât. The structure, too, seems more variable; north of the Tillar river a north-easterly strike prevails. The mass of porphyritic syenite forming Wajhiri hill, 5 miles from Vingorla, is considered to be intrusive.[2]

Gneiss of the Wainad.—Our next note upon these rocks refers to another gold-bearing tract, that of the south-east Wainád (Wynaad), on the uplands of Maisur (Mysore), at the north-west base of the Nilgiris. The position seems to be structurally important. In the little map published with Mr. King's report[3] on this ground the greater part of the area is shown to be within the region of the steady east-north-east strike which obtains in the Nilgiris and along the south-east edge of the Maisur plateau; but towards the north there is an area of troubled dips centred round two masses of granitoid rock forming the Munny Male and Yeddakul Male. Mr. King treats these granitic masses as (doubtfully) intrusive; north of them the foliation again passes into the normal north-north-west strike of the Sahyádri. This Nilgiri strike is noted as distinctly that of the lamination and bedding of the gneiss as well as of the foliation, the general dip here being southerly. Four belts of gneiss are recognised in the south Wainád: the quartzo-hornblendic gneiss of the northern face of the Nilgiris, and below (north of) it the Dayvallah band of highly felspathic gneiss with two minor belts of chloritic gneiss; north of this is the quartzose and ferruginous band forming the Marpanmudi range, beyond which is a broad area of more varied gneiss. The auriferous quartz-reefs are perhaps most developed in the Dayvallah band. Their lie is peculiar; the strike is north-north-west, corresponding with that of the gneiss in the country to the north, and at right angles to that of the rocks in which they occur, yet they generally have a low dip, from 10° to 30°, always easterly. One small trap-dyke occurs in the Dayvallah band; it runs east-by-north, nearly in the strike of the gneiss.

[1] Records, G. S. I., Vol. iv, p. 44.

[2] Some allowance must be made for discrepancies of nomenclature between different observers in these rocks: *e. g.*, some might call an altered micaceous sandstone, what others would name a quartz-schist.

[3] Records, G. S. I., Vol. VIII, p. 29.

Gneiss of the Nilgiris.—In the Nilgiris,[1] massive (obscurely foliated) gneiss prevails, but it is of a very different type from the massive gneiss of the South Máhratta country, which is granitoid and copiously felspathic. On the Nilgiri plateau it is in the very hornblendic variety of the gneiss, such as prevails over the northern portion, that the foliation is least marked. The rock is described as hard, tough, and black, breaking with an even fracture, and consisting of an intimate mixture of quartz and hornblende with some garnets. It was mistaken by early observers for syenite and greenstone. A similar rock, but with a variable proportion of felspar, is very common in the central parts of the hills. There are also several strong courses of a quartzo-felspathic gneiss, which has been taken for graphic granite. Locally this gneiss also contains garnets in great quantity.

A few thin dykes of trap have been observed in the Nilgiri hills, but no granitic veins. Small irregular veins of white quartz are common, but no reefs have been observed.

Gneiss of Trichinopoli and Arcot.—To the south as well as to the north of the Nilgiris, the gneiss of the low ground becomes well foliated and schistose. South of Coimbatur a band of limestone has been observed in the metamorphic rocks. Granitic veins are also common in this neighbourhood; they are especially conspicuous in the hill of Sunkerry Droog, but no intruded granite-mass of large dimensions occurs. Mr. H. F. Blanford, from whom the notes on the Nilgiris are taken, describes[2] a band of granitic rock to the north of Trichinopoli, and points out that this band is possibly a continuation of the very similar rocks of Coimbatur. In Trichinopoli, as to the westward, there is no massive intrusion; but the whole band (about 4 to 6 miles wide) may be considered rather as a network of veins running generally in the planes of foliation of a shattered band of highly foliated hornblendic gneiss, which is frequently twisted and contorted in every direction. The veins consist of a largely crystalline binary granite, mica occurring but rarely. The proportions of quartz and felspar vary greatly, and these ingredients sometimes affect the structure known as graphic granite. Mica is altogether a rare ingredient in the gneiss of this region of the peninsula.

A considerable area of the gneissic rocks of Southern India, from the Cauvery northwards, has been mapped in some detail. The geology has been described by Messrs. King and Foote, and the leading features have been made out, or at least suggested.[3] The belt of granitic intrusion

[1] Memoirs, G. S. I., Vol. I, p. 218. | [2] Memoirs, G. S. I., Vol. IV, p. 30.
[3] Memoirs, G. S. I., Vol. IV, p. 269.

already mentioned, along the north bank of the Cauvery, is on an anticlinal axis. Beds of variable gneiss and schists, with some limestone, dip from it on both sides. To the north they pass under the great mass of rocks forming the several clusters of hills in the Salem district, where, as in the Nilgiris, a syenitoid (*i. e.*, hornblendic) gneiss is very prominent. With it are associated the various magnesian schists from which the magnesite of the "chalk hills" is derived, and also the great beds of magnetite which have made Salem famous as an iron-producing district. These are not lodes, but regularly bedded masses of banded iron-ore and quartz, associated with the gneiss. With the aid of the very conspicuous outcrops formed by this rock, several great features of contortion have been made out, proving the strata to be frequently repeated at the surface.

In South Arcot, to the east of the Salem hill-groups, a considerable area is occupied by rocks having a very granitic aspect, yet showing in many places undoubted stratification, and occurring in great continuous ridges, which apparently form anticlinal and synclinal folds. The rock is composed of quartz and white and pink felspar. It frequently contains blocks, both angular and rounded, of hornblende schist. Altogether, the nature of this rock and its position in the metamorphic series are still open questions.

The distribution of the trap dykes in these metamorphic rocks is markedly peculiar, but it has hitherto received no satisfactory explanation. The dykes are very rare and small in the granitic band of the Cauvery, and also in the granitoid rock of South Arcot; on the other hand, they are extremely abundant in the areas of hornblendic schists and syenitoid gneiss. They mostly run at right angles to the bedding, but occasionally in the same direction with it.

North of Trichinopoli a change takes place in the direction of the strike of the metamorphic foliation analogous to that noticed in the Wainád: the east-north-east direction changes rapidly into north-north-east, parallel to the Coromandel Coast. The regularity of the coast-line is no doubt connected with this fact.

It is interesting to note how the main structural features of the fundamental rocks thus determine the actual configuration of the peninsula. All the fossiliferous deposits, and even the later azoic formations, are but patches on the weather-worn surface of this most ancient gneissic mass.

The Assam gneiss.—From the geographical point of view, Assam and the Shillong plateau could not be affiliated to the peninsula, but geologically this would seem to be their proper connexion, since the prevailing rocks closely resemble the gneissic and transition formations of Bengal, and differ widely from the rocks of the adjoining

mountains to the north and east. The structural characters bear the same relation: on the edges of the Shillong plateau secondary and tertiary strata lie quite horizontally, while much younger deposits have undergone intense disturbance in the contiguous Himalayan and Burmese regions. The plateau thus forms a wedge-like mass of neutral ground occupying an acute angle between two regions of contortion.

The ground to which these remarks apply is not known to extend beyond the Dhansiri river (Golaghát) to the north-east, though it is likely that the gneissic rocks stretch for some distance at least under the alluvium of Upper Assam. The principal area is the continuous hill-mass, 250 miles long, between the Dhansiri and the Bráhmaputra. It is only the southern border of the hills, where they are capped by the horizontal sandstones, that can be appropriately called a plateau. Even geographically this Assam range is independent, a system of deep longitudinal valleys separating it on the south-east from the Barail ridge, which belongs to the Indo-Burmese mountain system. A single name is much wanted for this well-defined orographical feature; at present it is spoken of in sections corresponding to the tribes who inhabit it—the Garo, Khasia, Jaintea, Míkir, and Nága. The Assam Range would be an appropriate title. The whole of the Lower Assam valley may be included in the same geological region, for the numerous hills protruding through the alluvium north of the Bráhmaputra consist of the same old gneiss, and not of the Himalayan type of metamorphic rocks.

The most interesting of these outcrops in the low ground of the Brámaputra valley is one observed by Mr. Mallet[1] within 200 yards of the tertiary sandstone at the base of the Himalaya on the left hand of the Rydak river, in the Western Bhután Duárs. It is really within the Sub-Himalayan zone, being up a river-valley, inside the mean outer boundary of the sandstones. The rock is thick-bedded hornblende-schist, a common type of rock in the Bengal gneiss, but one that is rare in the Darjeeling gneiss of the adjoining mountains. This is the only instance of close proximity of the azoic rocks of the peninsula to the Himalaya region.

The only observations hitherto made on this Assam gneiss prove little more than that it has a likeness to the Bengal rock, and that the general strike is the same. Some granitic intrusions occur in the transition rocks of the Shillong area, in connection with which they will be noticed.

A few observations on the gneiss of the Arvali region will be given with the description of the transition rocks.

[1] Memoirs, G. S. I., Vol. XI, p. 44.

CHAPTER II.

PENINSULAR AREA.

TRANSITION OR SUB-METAMORPHIC ROCKS, LOWER SERIES.

General remarks — The Bijáwar basin — Bijáwars of Bundelkhand — Gneissoid bottom-beds of the Kén — Dhár forest area — Middle Narbada area — Son-Narbada watershed area — The Son area — The Behár area — Gneissoid bottom-beds of Lakiserai — The Shillong Transition series — South-West Bengal — The Arvali region — Bijáwars of Bágh and Jobat—The Chámpanír area — The Arvali proper — Korana Hills — Maláni beds.

General remarks.—Of the lower transition rocks we can only offer a disconnected and unsatisfactory account similar to that already given of the metamorphic rocks, and for the same reasons—their intrinsic obscurity and the very partial examination they have received. The only difference is, that in the case of the transition series we must make the darkness more apparent by a brief discussion of the leading features of the case; even though this discussion leaves much unsettled, it will serve as a starting-point for fresh inquiry.

The lower transition series, it may be as well to repeat, consists of unfossiliferous schist, quartzite of various kinds, jasper, breccia, limestone, slate, and sandstone which are distinguished from some very similar formations classed as upper transition beds, by exhibiting a greater amount of alteration. Either by metamorphism, conformable sequence, or the intrusion of granitoid plutonic rocks, the lower transition series is connected with the gneiss, whilst the upper transition rocks are distinguished by the absence of any such connection.

The Bijawar basin.—The following remarks refer principally to the great band of sub-metamorphic rocks, stretching in a west-south-west to east-north-east direction obliquely across the peninsula from Bengal to the Narbada valley in Nimár. Geologically we may speak of this belt of transition rocks as the Bijáwar basin, although within the stratigraphical basin the Bijáwar formation is for the most part covered by Vindhyan strata. Owing to this fact, the northern outcrops of the transition series at Bijáwar, in Bundelkhand, are widely separated from their main exposure along the southern edge of the Vindhyan plateau. This principal band of transition rocks is about 700 miles long. There

are many interruptions of continuity by superficial deposits, but the whole forms one structural feature.

A principal doubt regarding the transition rocks of this basin is, whether we have to deal with one formation or with two; whether the rocks of the eastern side, in Behár, are the equivalents of those of the western side, in the Narbada and Upper Son region. The composition of the series is strikingly different in these two positions, and the relations to the gneiss are not uniform. The presumption is perhaps on the whole in favour of the eastern and western series corresponding to each other throughout; but it is well to suggest at once the doubt of the two being identical and to keep it in mind. Our description will begin with the Bijáwar area, then take up the west end of the Narbada ground, and thence work eastwards to Behár.

Bijawars of Bundelkhand.—The commonest bottom-rock of the Bijáwar formation in Bundelkhand is a quartzite. Locally it might be called sandstone. It is generally fine-grained, but sometimes, at the base, coarse and conglomeratic from containing pebbles of white quartz. It rests quite horizontally or with a slight dip upon a denuded surface of the gneiss, even in that most western part of the area, where, as was explained, the uppermost portion of the gneissic series is supposed to be found.

With this quartzite a hornstone-breccia and a limestone are intimately associated. They sometimes replace the quartzite as the bottom rock, or else are interstratified with it, or overlie it. The hornstone is compact quartz, more or less transparent or opaque, of yellow, brown, and red tints; the angular fragments included in it are generally of white quartz, and are always paler than the matrix. In some cases, if not in all, they are clearly the result of fracture; and of fracture not caused by contortion, for the breccia mostly lies quite flatly upon a firm support. Occasionally the former continuity of the detached pieces is evident; the mass looks as if thin bands of quartz had been shattered by concussion, or by shrinkage, then re-cemented in place, and the interstices filled by a more jaspideous form of quartz. The limestone, too, is highly silicious, the quartz appearing both as thin layers and as shapeless irregular segregations of chert.

These bottom rocks of the Bijáwar formation in Bijáwar are very irregular in distribution; in some sections there is no quartzite; in others, no hornstone-breccia, or limestone. The total thickness nowhere exceeds 200 feet. This unevenness of the basement-bed tends to suggest the unconformity of the succeeding deposits, but no confirmation has been

found of this suggestion. On the contrary, sub-schistose shales like those of the upper part of the group are sparingly intercalated with the limestone and quartzite.

More or less earthy ferruginous sandstone, locally somewhat conglomeratic, is the prevailing upper rock, and is associated with rusty shales, incipiently schistose. The iron in these rocks is locally concentrated into a rich hæmatite which has been extensively worked. Several thick but discontinuous beds of dioritic trap occur in the bottom part of the group.

The whole Bijáwar formation in the typical Bijáwar area is probably not more than 800 feet thick. The strata generally either have a very low south-easterly dip, or are quite horizontal; but in a few places to the south, before they become covered up, they are seen to have undergone a considerable amount of crushing, which has not in the least affected the Lower Vindhyan rocks immediately overlying. The general immunity from disturbance in this small area may be due to the original shallowness of the deposits here, where they thinned out over the mass of gneiss, which afforded an unyielding support against compression. It is probable that the transition basin deepens rapidly to the southward beneath the Vindhyan rocks, and that the complete unconformity between the Bijáwars and the Lower Vindhyans, as observed in the Son valley, rapidly replaces the general parallelism of stratification that obtains in the Bijáwar area. East of the Kén (Cane) the transition rocks soon disappear, being totally cut out by the Vindhyans overlapping on to the old gneiss. From a little west of Allahabad all the lower azoic rocks are concealed by the Gangetic alluvium stretching up to the base of the Vindhyan scarp.

Gneissoid bottom-beds of the Ken.—In the east, at Panduah hill and the Kén (Cane) river, a trappean rock occurs below the bottom quartzite, and has received various interpretations from different observers. It was at first[1] grouped with some pseudo-igneous and gneissoid rocks occurring in this section below the normal base of the Bijáwar series. Subsequently by another observer it was classed as a local occurrence of the Bijáwar trap, by a third as the outcrop of a dyke in the gneiss. It is certain that at the Kén the character of the bottom Bijáwar rocks changes rapidly; the strong quartzite thins out suddenly; and a prominent rock on the continuation of its strike is a peculiar sharply cellular quartzite, much quarried for quernstones; but the beds associated with this quartzite are sandstones and shales like those of

[1] Mem., G. S. I., Vol. II, page 37.

the upper part of the series. In the river, and certainly below the horizon of the bottom quartzite of the Bijáwars west of the Kén, there are two or more steady outcrops of pebbly sandstones having the same low south-easterly dip as the adjoining Bijáwar strata, but occurring in the midst of thick pseudo-crystalline gneissic rocks. It is important to notice these observations with a view to their verification or correction, for these sandstones seem to have escaped the notice of the later observers, and they are important as fixing the affinities of the associated gneissic strata with the transition series rather than with the normal gneiss of Bundelkhand. Very similar rocks are found far to the east in an analogous position at the base of the transition series in Behár, and again extensively in the Arvali region; and the whole question is of interest as bearing upon the elucidation of the great gneissic series—as to whether we must not recognise some rocks of this class that are not metamorphic in the full sense of the word, *i. e.*, ordinary sediments transformed, but that are merely granitic or gneissic detritus reconsolidated.

Bijawars, Dhar forest area.—Proceeding from Bijáwar in a south-west direction obliquely across the plateau, where the Vindhyans are for the most part covered by the Deccan trap, we should strike the Narbada about Hindia, at the west end of the wide alluvial plain, 200 miles long, which is in India designated especially as the Narbada Valley. West of Hindia there is a considerable area occupied by transition and gneissic rocks. They abut on the west against the Vindhyan rocks of the Dhár forest[1] area, but appear again in the north of this area and west of it about Barwai. These transition strata have been fully recognised by Mr. Mallet[2] as bottom Bijáwars, consisting of quartzite, hornstone-breccia, and chert-banded limestone identical with those of Bundelkhand. No associated trap rock was observed.

These rocks are more disturbed here than in Bijáwar, but Mr. Mallet describes their relation to the gneiss to be the same, *i. e.*, total unconformity. The quartzite is often found quite flat and surrounded by vertical strata of the metamorphics. It is only possible to question this view by supposing that what we take to be stratification in the metamorphics is a result of molecular forces acting on lines of cleavage. This possibility has been forcibly argued with reference to this very area,[3] and connected with the suggestion that the two series may be very

[1] The Dhár forest is a tract of wild forest-clad hills through which the Narbada flows between Hindia on the east and Barwai on the west.

[2] Unpublished report.

[3] Mem., G. S. I., Vol. VI, pp. 193-202.

closely allied, the gneiss being more or less a metamorphic condition of the Bijáwars.

The possibility and the suggestion are based upon two facts: that the strike of the foliation-planes in the gneiss agrees constantly with the strike of the cleavage-planes in the transition series, and that the chert-bands in the Bijáwar limestones do certainly sometimes occur in the cleavage-planes and not in the bedding. On the other hand, it may be remarked that the lines of disturbance, the synclinal and anticlinal axes, in the Narbada valley, even amongst rocks of much later age than the Bijáwars, observe the same strike as the cleavage and foliation-planes in the old rocks, and that thus at the outcrop the strike of cleavage and bedding would generally agree. As to the chert-bands, they are in any case admittedly of segregative origin, and so cannot be taken as a clue to the arrangement of materials differently aggregated.

Upon the settlement of this question as to the relations between the metamorphic and transition series, it will depend whether the gneiss of the Dhár forest should be affiliated to that of Bundelkhand or to the supposed younger gneiss of Bengal. The composition of the Dhár forest gneiss is in favour of the former relation; and, as there probably is still a broad band of the Bijáwar basin to the southward, the position is not opposed to this view.

Here, as so often elsewhere, a doubt occurs as to the intrusive character of the more granitoid varieties of the gneiss. Some hornblendic and earthy schists of this area, as in the Narbada above Mortaka, where the Indore railway crosses, have been included with the gneiss; but it may be questioned if they do not belong to a transition group older than the Bijáwars.

Middle Narbada area.—Proceeding eastwards up the Narbada valley from Hindia, no rocks are exposed on the northern side, under the Vindhyan scarp, for a distance of 120 miles, to where the Bijáwars form low hills in the Narsingpur district. The cherty limestone and breccia are the only beds seen here; but this may be because the lower rocks are covered by alluvium. The gneiss does not appear again on this side of the valley.

Along the south side of the river, on the edge of the Gondwána formations of the Sátpura hills, there are more frequent outcrops of the transition rocks. The most westerly are near the Moran river, about 30 miles east of Harda, where some narrow ribs of the cherty limestone protrude through the Deccan trap, which from this point covers all the rocks to the west. On this south side of the valley, also, the cherty limestone, generally much contorted and brecciated, is the rock

most frequently seen ; but other beds do occur, as in the Bári hill, 15 miles east of Sohágpur, where a considerable thickness of trappoid and earthy rocks is exposed, the latter being so little altered as to be easily mistaken for the Talchir shales of the contiguous Gondwána area. In many places on this south side of the valley, gneissic rocks of doubtful character occur close to the Bijáwars ; and the relation between the two series is certainly not simple superposition, both being found at the same level in closely adjoining positions.

Son-Narbada watershed area.—At the head of the Narbada valley in the north of the Jabalpur district there is a continuous exposure of Bijáwar rocks between the Vindhyan and Gondwána areas. We are here on the watershed of the peninsula, between tributaries of the Narbada and the Son. Both these streams have their sources well to the south of the line of their principal valleys, the former flowing from Amarkantak, at the eastern edge of the Deccan trap forming the Mandla plateau; the latter rising not far off, at a slightly lower elevation, in the gneissic rocks that extend to the eastwards from beneath the trappean area.

The space between the Vindhyan and Gondwána basins is very much narrower here than to the west, being only 12 miles wide. The Bijáwars cover the whole ground, but they only form hills 300 to 400 feet above the general level, and no rocks are found very different from those already noticed in the formation. The fact that the beds which we have taken to be the base of the Bijáwars still continue, in the absence of gneiss, to be the prevailing rock exposed along the northern outcrops in the Narbada area, will have suggested that no structural change in the concealed features of the basin has occurred in that position, and that the gneiss probably lies at no great depth; and we learn from the section at the watershed that, here at least, these supposed bottom-beds occur across the whole zone.[1] The section is described as a shallow synclinal; but it scarcely deserves this name, for the bottom, or at least the lowest, rock is as freely exposed in the centre as elsewhere. There must, however, be something of the nature of a basin, as the underlying gneiss only appears along the south margin.

All the leading characters of the formation already noticed are represented here, with a greater development of the argillaceous element. Fine earthy slates of reddish tints are the lowest strata seen; their upper beds are associated with the quartzite which underlies the limestone and is intercalated with it; and the limestone itself is not so constantly cherty as has been described elsewhere. Above the limestone, ribboned jasper beds,

[1] Our notes upon this ground are from unpublished reports by Mr. C. A. Hacket.

passing locally into bluish quartzite, are well developed, and both jasper and quartzite are frequently brecciated. Earthy schists, locally conglomeratic, are also freely associated with this band. The rich iron-ores so largely worked by the natives in this neighbourhood are a concentrated development of the hæmatite and jasper bands of this horizon. Above the iron-band there is again a considerable thickness of earthy schists. Bedded trap occurs throughout the series.

As is implied by the facts already stated, these rocks are not on the whole greatly disturbed. Low undulating dips prevail, although locally there is much contortion. The highly inclined planes, so general in the schists, are of cleavage, not stratification. The thickness of the whole series exposed cannot be great, probably it is under 1,200 feet; and there is scarcely any presumption that the conformable slates beneath the limestone attain any great thickness underground.

Notwithstanding these conditions, the rocks are in an advanced state of metamorphism. The limestone is generally crystalline, the schists are often highly micaceous, hornblendic and garnetiferous, and the iron-ore is mostly the micaceous form of hæmatite. The section in the Narbada at the well known "marble rocks," 10 miles south-west of Jabulpur, exhibits the high degree of alteration and local disturbance to which the Bijáwars have been subjected in this region.

From observations obtainable in this neighbourhood we could only suggest an explanation of these conditions; but from analogy with cases better exposed elsewhere, it is probable that the massive granite, forming such conspicuous rock-features in and near the station of Jabalpur, is of post-Bijáwar age. Here the granite is entirely surrounded by later formations, so that direct evidence of the connexion between it and the Bijáwars cannot be found. The relation of the Bijáwars to the gneiss is better seen. About 7 miles north-east of Jabalpur there is an exposure of true gneiss. Mr. Hacket describes the actual contact of the Bijáwars with this rock, where *upper beds* of the transition series are crushed against the gneiss, and rest upon it, without exhibiting any change or gradation of mineral characters. This is a strong point in the case to be stated presently, as to whether we have to deal with two transition formations in this basin, or with two gneissic series adjoining it.

The Son area.—Immediately to the east of the flat watershed, the band of transition rocks is entirely concealed by an extensive spread of laterite and alluvium, and beyond this we get into the region of the Lower Vindhyans, which stretch to the south of the scarp of the Upper Vindhyan plateau until they nearly come into contact with the Gondwána deposits. After crossing the Son, however, the band of transition rocks

again expands gradually to a width of 25 miles in the south of the Mirzapur district. It is here we encounter the question whether one or two formations occur within this basin of transition rocks.

The northern half (about 10 miles wide) of the transition band, at a little west of the Rehr river, is formed of regular Bijáwar rocks, such as we have hitherto seen them—quartzites, hornstones, banded jasper and hæmatite, limestone and slates or schists, with abundance of intercalated trap. The whole band strikes against and under the Lower Vindhyan strata, where the Son takes a southerly bend opposite Agori. The southern half of the transition band (15 miles wide), as well exposed in the Rehr, is entirely composed of fine slates, with intrusive trap only, the dykes being mostly transverse to the bedding. Both groups are so intensely crushed together that no decisive section of the junction has been found in the low jungle-covered hills. Mr. Mallet mentions an instance at Ubra, at the north end of the section in the Rehr, where a quartzite of the northern set seems to cap a ridge of the slates; but this case is not clear, and the question of the relation is quite open, except that it certainly is not one of horizontal transition, the two contrasting deposits being in full force and character in juxtaposition.

The western extension of the section into the Rewah country has been but imperfectly examined. Already at the Gopat the slates have disappeared, and the northern band of true Bijáwars is in contact with the southern gneiss. In this region, where the Son above Bomársan takes a bend into the area of the transition rocks, there is a good instance of local metamorphism: throughout the whole length between the Gopat and the Son at Murai, the transition rocks along the Lower Vindhyan boundary, distinctly recognisable as Bijáwars, are in a gneissose condition, and granitic intrusive rocks occur in them. The character of the contact of these beds with the main gneiss to the south is, however, of the kind described by Mr. Hacket north of Jabalpur, abrupt rather than transitional; but it is certain that they themselves are locally gneissic, and have been affected by granitic intrusions.

If it were certain that this character of the contact of the ferruginous Bijáwars with the southern gneiss is constant, and has no connection with faulting and crushing, and also that the gneiss of the Rehr and the Gopat are the same, we could at once affirm the distinctness of two transition groups in this ground; for the junction of the slates of the southern band with the main gneiss is perfectly transitional—a gradual alternating passage from the strong gneiss, through gneissose and other crystalline schists, into the fine clay-slate, as is well seen in the section in the Rehr. But while doubts exist upon these two conditions, it must

remain possible that these slates of the Rehr are only a bottom member of the Bijáwar series.

Behar area.—East of the Rehr and the Kanhar several large inliers of gneiss and of granitoid rocks, of more or less intrusive character, occur within the slate area, and at the Koel gneiss is the only rock seen below the Vindhyans. This encroachment of the crystallines upon the zone of the transition rocks is extended in Behár, where gneiss reaches for some miles north of the trunk road west of Gya, quite across the strike of the slates. Several hills isolated on the alluvial plains in this neighbourhood are of thorough granite.

Immediately east of Gya, transition rocks appear again, on the prolongation of those in the Son valley, and having the same strike. They form several groups of hills in East Behár, most of which stand clear of the main gneissic area, being more or less isolated in the alluvial plains. These are the Maher (Muhair), Rájgir, Shaikhpura, Karakpur (Curruckpore), and Ghidaur hills. Those of Mahábar and Bhiaura are on the northern margin of the gneissic upland. The aspect of all these hills at once shows that they must be formed of very different rocks from the Bijáwars of the west, and suggests also that all these Behár rocks belong to one formation. They present, generally on every side, scarped faces formed of massive quartzites, the associated schists or slates appearing obscurely in the valleys. All the peculiar Bijáwar rocks are wanting; there is no limestone, hornstone, jaspideous ironstone, or bedded trap. The only similar rocks in the west are the slates of the Rehr section; and there the quartzites, which form such a prominent part of the transition series of Behár, are absent.

We have a somewhat detailed description of the Mahábar and Bhiaura hills by Mr. Mallet;[1] and the relation of the two rock-series is shown to be very peculiar. The transition series here consists of three divisions: an upper, composed exclusively of strong quartzites, as seen in Mahábar hill; a thick middle band, in which fine mica-schists largely predominate; and a basal member, in which quartzites again occur, sometimes in great force, as when forming the Bhiaura ridge, but at no great distance they may be altogether wanting. This proved inconstancy of the bottom quartzites will (by leaving their presence or absence a character of no importance) make it easier to correlate the group with other rocks; while their frequent presence here is of great service by removing the doubts that so often arise as to whether planes of lamination in schistose rocks of uniform composition are due to bedding or to cleavage.

[1] An abstract of it, without a map, is published in Rec., G. S. I., Vol. VII, page 32.

It would be difficult to draw a more irregularly intricate line than the transition and gneiss boundary on Mr. Mallet's map. Near the Bhiaura and Mahábar ridges there is some approach to an average east-and-west strike of the boundary, but as the plane of junction between the two series rises to the south, its line of outcrop meanders about in the most devious manner. This is not due, as might easily occur, to the irregular denudation of two deposits in flat parallel superposition. Here the lower (older) rock, as a rule, forms the prominences, between which the schists are deeply buried; yet the bedding in both rocks is found to follow the intricate twistings thus produced, the actual junction being generally inclined at a high angle. If the whole surface of contact of the two series could be cleared to view, it would be something like that of the sea in a cyclone.

Even in the absence of the bottom or Bhiaura quartzites, the boundary can always be fixed with precision, on account of the strong contrast between the fine mica-schists and the coarse gneiss; yet the transition rock seems to have fully partaken in the metamorphic action, for it is a thoroughly crystalline garnetiferous mica-schist up to the base of the Mahábar quartzites. Similar variations are found in the gneissic series at the contact: on the north side of the Bhiaura ridge the bottom quartzites lie steeply against the dome-gneiss (p. 20); elsewhere schistose gneiss occurs at the boundary. The dykes and massive outbursts of pegmatitic granite of this region are principally exhibited in the transition series.

A very close connexion is thus established in this position, by conformity of stratification and by a common metamorphism, between the transition rocks of Behár and the gneiss in contact with them; and it is probable that a large part of the gneiss of Bengal is of the same age as that at the boundary of the transition series. There is, for instance, a very distinct outlier of the Mahábar schists and Bhiaura quartzites on the plateau, 80 miles to the south of the boundary in Behár, just north of the Grand Trunk Road at Barhi.

There can scarcely be a doubt that the rocks of the Rájgir and other detached hills of Behár are of the same formation as those of Mahábar, and so the contrast of their mineral condition is interesting. The latter have undergone general crystalline metamorphism, the former have only very locally suffered this change, being for the most part still in an earthy, slaty condition. Yet it would seem that they too are closely surrounded by crystalline rocks; for whenever rock is exposed through the alluvium near these hills, it proves to be granitic. At one spot near Ghansura, on the north side of the Rájgir range, there is a contact showing

distinct intrusion of granite into the soft earthy schists. It is an ordinary ternary granite, not like the pegmatitic granite of the Mahábar region. In the immediate neighbourhood of Gya many forms of special metamorphism and of contact-action are well exhibited. One result of special metamorphism on the earthy ferruginous schists is to convert them into a soft massive trappoid rock, much worked into images and vessels. It would seem even that the conversion had gone the length of producing in this rock the plasticity commonly ascribed to fusion.

The amount of disturbance is rather greater in the detached hills, where the rocks are less metamorphic, than it is in the Mahábar region; and the very peculiar confused form of contortion—noticed above as marked in such detail by the surface of junction where the transition series rises to the south against the main gneiss—is well exhibited throughout the formation, only in larger proportions in the top beds of the series. Mahábar ridge itself is a typical instance of this structure: it is a long, narrow, synclinal ellipse, the quartzites dipping at a high angle all round towards the centre, and curving continuously at each end of the axis. The Rájgir range contains a pair of such ellipses compressed together, the quartzites being for the most part quite vertical along the sides. The Karakpur (Curruckpore) hills, which form the largest of these groups, are a congeries of these discontinuous flexures, little or no regularity being observed in the direction of the axes of contortion. This structural feature as a whole is very puzzling, and apparently inexplicable on the conditions of rigidity which are sometimes considered essential in geological dynamics.

Gneissoid bottom-beds of Lakiserai.—There is still a point to mention in connexion with these transition rocks of Behár. We have seen them in the Mahábar ground resting in apparently regular sequence on the gneiss. The only contacts observed about the Rájgir hills are with intrusive granite; but some distance to the north of this position massive gneiss is exposed in the Barábar hills on the Gya and Patna road. On the east and south of the Karakpur hills the quartzites are in contact with gneiss, but the ground has not been critically examined; on the north a boss of granite appears close to the base of the hills at Urain, south of the loop-line near Kajrah station. We have still to notice the rock underlying the quartzite in the small ridge of Shaikhpura and in the little hills a few miles to the east at Lakisarai (Luckeesarai), the junction station for the chord and loop lines of the East Indian Railway. There can be little doubt that the quartzite of these localities is the bottom-rock of the Behár transition series, the Bhiaura quartzite. In the Shaikpura ridge it rests steeply against a rock having the texture of a thoroughly crystallised coarse

granite, but completely decomposed. The relative position of the two rocks is precisely that of the Bhiaura quartzite and the dome-gneiss. Along a steady outcrop of some 2 miles long no feature of special intrusion was observed, and there is no extra metamorphism at this junction. The only contact-action that occurs is of secondary origin, in the formation of layers and vein-like strings of a sharply cellular quartz-rock much used for making hand-mills.

This section is noticed in connexion with the more decided one at Lakisarai, only a few miles to the east, on the same strike, where the quartzite again rests against an amorphous mass of pseudo-crystalline granitoid rock, but of much less sharply defined texture than at Shaikhpura, and in which strings of pebbles can be detected. This is underlaid by strong beds of coarse conglomerate having the same dip as the overlying quartzite. The pebbles and boulders in this conglomerate are mostly subangular, and are exclusively of varieties of quartzite like those of the overlying formation, none being of crystalline rocks; they often appear elongated in the direction of the foliation, and adhere firmly to the matrix, which is a quartzose, sub-gneissose schist. Just east of Dharárah station some masses of this rock protrude through the alluvium close to the base of the Karakpur hills. Another outcrop of conglomeratic schist was observed under the east end of the Gidhour range and dipping towards it.

These Lakisarai beds remind one forcibly of the pseudo-gneiss observed conformably underlying the Bijáwars in the section of the Kén river in Bundelkhand (page 30), and the suggestion revives, however slightly, the question of the possible correspondence of the transition groups in the two areas.

There is another rock frequently found with the undulating gneissic rocks of Behár and elsewhere in this zone, or protruding from the alluvium near the hills, that suggests the same connection. It is a jaspideous quartzite, often brecciated, and not unlike the bottom Bijáwar rock of Bundelkhand and the Dhár forest. It commonly has the same moderate dip as the rocks with which it occurs; but when vertical or crushed, it is readily mistaken for fault-rock or vein-stone.

If the suggestions here made—of pseudo-gneissic beds occurring locally at the base of the Bijáwars, and related to that formation—should be confirmed, a closer connection might be thought of between the Bijáwars and a portion of the underlying gneiss in Bengal, than is implied by the simple parallelism and transitional metamorphism seen in the Mahábar sections. Suggestions of an opposite tendency can, however, be pointed out from observations recorded in preceding paragraphs: it was stated (p. 35) that the contrasting groups of transition rocks in

the northern and southern portions of the section in South Mirzapur, cannot be in any degree representative of each other by horizontal transition; and the presumption there would be strongly in favour of the southern beds, the slates of the Rehr being the older of the two. If the Behár rocks had to be affiliated to either of these exclusively, it would certainly be with the latter group; and if with the whole series of Mirzapur, the Mahábar quartzites would have to represent the true Bijáwars, which would thus be placed at the top rather than at the bottom of the local transition series. To adjust this point of view, we should have to suppose a break in the Bundelkhand section between the true Bijáwars and the gneissoid beds of the Kén.

The Shillong transition series.—It has been already explained (*supra*, page 26), that the gneissic formations in Lower Assam and the hills to the south are more closely allied to those of the peninsular region of India than to the metamorphic formations of the Himalaya. This relation holds also for the transition rocks, which are largely developed on the south side of the hills, where the sub-metamorphic beds are for the most part covered by the horizontal cretaceous rocks of the plateau, but are exposed in the deep ravines that penetrate to the very axis of the range. The lateral extension of these transition rocks has not been ascertained; on the central cross-section in the Khási country, they stretch for 30 miles from near the south margin of the plateau to beyond the watershed north of Shillong, the culminating ridge with summits 6,450 feet high being formed of the quartzites of the transition series, which rocks have hence been described as the Shillong series.[1]

The position of these Shillong beds is approximately on the continuation of the long tract of transition rocks described as the Bijáwar basin, and the rocks themselves have a general resemblance to those in Behár, at the east end of that tract. They consist of a strong band of quartzites overlying a mass of earthy schists. There also occur intrusively great masses of granite and of basic trap-rock. The former may well represent the similar rock seen to be intrusive into the slaty schists of Rájgir, and for the latter an origin has been assigned similar to that already suggested for certain trappoid rocks in Behár. Thus altogether the affinity is sufficiently marked to introduce the notice of the Shillong area in sequence with that of Behár. In the lofty and deeply eroded ground of the Assam hills the sections are much more favourable for study than on the alluvium-smothered plains country, and some very puzzling observations have been recorded regarding the relations of the hypogene rocks to the Shillong series.

[1] Mem., G. S. I., Vol. VII, page 137.

The lithology of these Shillong rocks varies much according to local conditions of metamorphism. In places the quartzites are quite friable and might be called sandstones; but this state is probably due to partial decomposition, for the intimate texture always reveals the effects of chemical change. Generally the rock is very firm and more or less schistose. It is coarser grained than is common in the Behár quartzites, and at the base, immediately over the slates or schists, there usually occurs a conglomerate, often of considerable thickness, made up chiefly of quartz pebbles, but with some rounded fragments of coloured quartzites. Still, so far as has been made out, the quartzite is conformable to the schists; but in such troubled ground it is difficult to make sure of such a point. The schistose beds also exhibit much variety of texture, from ordinary clay-slate to well-foliated schists and gneiss. These changes are simultaneous in both quartzites and schists, and it is noteworthy that the increase of metamorphism is towards the south, away from the area of the old gneiss.

The relation of the transition rocks to this gneiss has not been made out. On the only section of which we have critical observations, nearly due north-and-south through Shillong, the boundary with the gneiss occurs in the low jungle-covered hills, where observation is almost impossible. The dividing line between the two series crosses the high range to the west of our section, and it is there that the junction should be examined. The observation already noted, that the metamorphism increases to the south, would suggest that the junction of the schists with the main gneiss to the north may be lithologically abrupt. At the southern boundary there is a steep plane of contact between the highly altered transition rocks and the great accumulation of bedded eruptive rock known as the Sylhet trap, supposed to correspond with that of the Rajmahal hills, and therefore to be of Jurassic age. The cretaceous sandstones lie evenly and unconformably on both formations.

In the midst of the transition area there is an extensive exhibition of eruptive rock, of very different character from the Sylhet trap. It is a dense, massive, basic diorite or greenstone. The high road between Surarím and Mauphlong crosses this rock continuously for 5 miles in the gorges of the Kálapáni and Bogapáni rivers. The direction of the road is oblique to the strike of the rocks; but at right angles to its outcrop the greenstone is fully a mile wide. It nowhere betrays any bedded structure, and its intrusive character is not so marked as might be expected with so extensive a display of igneous rock. There is, however, sufficient evidence of intrusion from this greenstone: a well-defined dyke passes from the main mass into

the quartzite of the ridge, about half a mile south of Mauphlong. Elsewhere one may walk for miles along the junction of the two rocks without finding any signs of penetration of one by the other. The general circumstances of this trap have suggested the conjecture that it is in great part the result of the conversion *in situ* of the slates beneath the quartzites.

The relation of the granite, or at least of the larger masses of the crystalline rock, to the transition formation, is also very puzzling. Two such masses adjoin the high road across the Khasia hills. One is the Molím area just south of the Shillong ridge, and close to the road between Mauphlong and Shillong. At Molím this granitic tract is 5 miles wide. Its extension to the east is not known. The other area is much more difficult of approach, the granite being only exposed in the deep gorges under the sandstones of the plateau, as on both sides of Surarím.

The rock is a thorough granite; it commonly affects a spheroidal structure, and it is composed of pale pink orthoclase, often in large crystals, a small proportion of very pale greenish oligoclase, a little dark green or brown mica, and abundance of disseminated hyaline quartz. There can be no question that these great granitic masses are of later origin than the transition series; for the total want of symmetry in the arrangement of the surrounding sedimentary rocks forbids the supposition that they could have been deposited round the granite; yet the same absence of any apparent connection between the form of the intrusive masses and the disturbance of the transition rocks is very difficult to understand. The quartzites (the upper member of the transition series) are generally found at the boundary, but their dip and strike are quite independent of the proximity of the granite, as if their contortions had been fully established before the granite was introduced, and remained quite unaffected by it. The facts seem totally to preclude the notions of fracture and compression commonly associated with the word intrusion. The supposition of the mass being faulted into position also lacks any corroborative evidence; the boundary lines are all rounded, and show no symptoms of fissuring. It is as if a great hole had been burned out of the old stratified rocks and the crystalline mass let in, or as if the transition rocks had been converted into granite up to a certain boundary without affecting the area beyond that line. Yet the facts seem equally against the operation of any agency like molecular transfusion (diagenesis); for the junction is quite sharp, the quartzites not being more altered at the very contact with the granite than away from it. In keeping with all these negative characters is the fact that

no dykes or veins of granite have been observed issuing from these great masses (that of Molím), nor even in their neighbourhood. This is the more remarkable, because dykes and veins of similar granite are not uncommon in the southern part of the area, where the general metamorphism of the transition series is so much greater as to suggest that the focus of hypogene activity lay in that direction, beyond the present limit of these formations, in the ground now occupied by the Sylhet trap. It is also in agreement with the facts and suggestions recorded to note that the granite is younger than the old dioritic Khasia trap: in the bed of the torrent under Surarím, on the east, several small dykes of granite are seen ramifying through the diorite.

South-West Bengal.—The gneissic uplands of Hazáribágh and Chutia Nágpur (Chota Nagpore), about 120 miles wide, separate the transition rocks of Behár from those in South-west Bengal, occupying parts of Mánbhúm (Maunbhoom) and Singbhúm (Singbhoom) districts, and stretching far to the west into the Garhját States, the whole transition area being about 150 miles long from east to west and 80 miles wide.[1]

Although the total thickness of this series must be great, no distinctive zones are marked in it. From top to base it seems to be an indiscriminate alternation of quartzite, quartzite-sandstone, slate and shales, hornblendic, micaceous, talcose, and chloritic schists, the latter passing into potstone; also some bedded trap.

Several large inliers of gneiss occur within this basin of transition rocks. Around some of these inliers, the boundary is quite natural, *i. e.*, in its original condition, as at Chaibássa, where shales and sandstones rest flatly and quite unchanged upon the coarse gneiss of the principal inlier, and the unconformity of the two series is further proved in this case by the fact that the underlying gneiss is profusely traversed by trap-dykes which do not penetrate the surrounding deposits. The boundary between the transition rocks and the main gneiss of Bengal on the north is said to be a fault, on account of the more or less continuous presence along it of a rib of vein-stone. This boundary occurs, however, at the base of a long descending section of the transition rocks, and the beds along the line of junction are such as elsewhere appear as bottom-beds of the transition series. To the east, about Súpur, there are outliers of the slate series beyond the supposed fault-boundary, and at Borobhúm is an inlier of gneiss a short distance inside it. We can at least conclude that the junction here, whether faulted or not, is abrupt, *i. e.*, without any gradation of stratigraphical or mineralogical characters. In this part of the basin, the maximum of

[1] Our few observations on this ground are taken from manuscript reports by Mr. V. Ball.

disturbance and of metamorphism seems to occur away from the boundaries. Further to the west, however, the junction of the slate and gneissic series is described as transitional; and granite veins penetrate the shales without much affecting them.

The most striking feature of this area is a mass of dioritic trap running continuously, nearly east and west, through the centre of the transition basin, but varying in width. Dalma hill, 3,050 feet high, is formed of this rock; and here the outcrop is nearly 3 miles wide. The trap is described as a great dyke, occurring along the axis of a synclinal trough. As the succession of the strata on opposite sides of the synclinal do not correspond, there would seem to be faulting accompanying the fissure. The composition of the dyke is rather peculiar: the axis of the Dalma ridge is formed of a decided breccia, the rock on the flanks being compact or amygdaloidal, with included bands or nests of indurated chloritic schists. The transverse section of it, north of Rámgarh, a little to the west of Dalma, is as follows:—

1. Indurated chloritic schist.
2. Porphyritic trap.
3. Indurated chloritic schist.
4. Compact and amygdaloidal trap.
5. Indurated chloritic schist.
6. Brecciated trap.
7. Indurated chloritic schist.
8. Brecciated trap.

The Arvali region.—The largest area of transition rocks in India is the Arvali (Aravulli) region; but so little is known of it that nothing like a systematic description of the formations is possible. That gneissic rocks largely prevail in the southern and central part of the area, and submetamorphics in the north, has long since been noticed; it is only quite recently that Vindhyan strata have been observed to the west of the Arvali axis. The discovery at the same time of plant-bearing beds, perhaps specific representatives of some Gondwána group, at the base of the Jurassic deposits of Jesalmir, suggests the possible occurrence of outliers of this formation within the area.

The marine Jurassic beds of Western Rájputána form to the westward the natural limit of the Arvali as a geological region. It is, however, a boundary that can only be fixed at a few points, the whole surface being greatly covered by superficial deposits, consisting largely of blown sands. The same difficulty of demarcation is still more felt to the north. The greater part of the Punjab plains is of recent, scarcely pre-historic, origin, all the great rivers being still for the most part occupied in raising their beds; but so far as we know of its underground geology, the whole of this country belongs to the Arvali rock-area. The few small hills on the Chenáb, at Chiniot and Kariána, within 40 miles of the Salt Range, are

of sub-metamorphic rocks, and presumably greatly older than the Silurian or pre-Silurian beds at the base of the section in that range. This is by far the nearest point of approach in North-Western India between the Peninsular and Himalayan formations, to which latter region the Salt Range evidently belongs. Thus the Arvali rock-area, or geological region, has a much wider extension than the geographical feature from which the name is taken.

Bijawars of Bagh and Jobat.—In the extreme south-east of this region, in the Lower Narbada Valley at Bágh and Jobat,[1] the Bijáwar formation has been recognised, specifically identical with the beds in the Dhár forest (*supra*, page 31), the two localities being separated by 80 miles of Deccan trap. This interval, however, is not the principal reason for separating these western localities from the Bijáwar basin: throughout this latter area, for several hundred miles, the strike of the bedding, the cleavage and the foliation in all the rocks, is steady to east-north-east, whereas in the Bágh country the strike in both gneiss and Bijáwars is north-west to south-east. This distinction would, indeed, afford an equally good reason for detaching the Bágh ground from the Arvali region, where the dominant strike is north-east to south-west; but the fact that the underlying crystalline rocks are continuous, must be taken to decide the question: it is in connection with the Arvali area that the affinities of the Bijáwars of Bágh and Jobat would be directly studied.

All the most characteristic rocks of the formation are well represented at Bágh—quartzite, hornstone, breccia, and cherty limestone, and here again interbedded trap occurs, though not found in the Dhár forest area; clay-slate, too, is here more prominent. The town of Bágh stands on the small triangular area of Bijáwars near their south boundary, which is overlapped by cretaceous rocks; the other two boundaries with the gneissic rocks are faulted. The area only extends 7 miles to the north-north-west, and 5 miles to the east of Bágh. The rocks are highly disturbed and cleaved, but the metamorphism is local and moderate.

Jobat is about 16 miles west-north-west of Bágh, and stands at the southern point of another small patch of transition strata. The conditions are peculiar and puzzling. The only recognisable Bijáwar rock is a very typical one, a ferruginous jasper, locally brecciated, with veins of hornstone. It lies almost horizontally, forming a low, scarped plateau. Along the north-east border, south of Anthi, black and grey schistose slates appear between the jasper and the metamorphics, the foliation and apparent bedding in both schists and gneiss being parallel, with a high

[1] Described, Mem., G. S. I., VI, pp. 193 to 202, 303, and 314.

dip to the south-west. Both rocks are highly charged with vein-quartz, suggesting local crushing or faulting. Accepting these beds between the jasper rock and the gneiss as Bijáwars, the similarity in the composition of the transition and gneissic series and their general affinity are considerable: within the transition area, north-west of Saimulda, there are outcrops of talcose and schistose slates and quartzite, with a strong band or vein of coarsely crystallised ternary granite distinctly intercalated in the cleavage-strike (apparent bedding). The schistose slates at the contact of this vein are not more crystalline than usual, and the granite differs from that generally found in the metamorphics. West of Saimulda, close to Andhári, the slates appear to pass along their strike into gneiss and hornblendeschist, becoming more and more crystalline as the metamorphics are approached; but there may be a concealed fault between. Near Jobat, and again 3 miles to the north-west (along the strike), friable calcareo silicious rocks, with seemingly contorted bedding, underlie the horizontal jasper rock.

It is evident that the question here turns upon the point before alluded to (*supra*, p. 31), whether or not the apparent bedding in the schists is real or only induced. In the former case, they can have no connexion with the jasper bed, which would then be the only representative of the Bijáwar formation in this ground. This is, perhaps, the true solution of the difficulty.

The Champanir area.—In the same south-western quarter of the Arvali region there is another basin of transition rocks. It lies between the gneissic upland and the alluvial tracts at the head of the Gulf of Cambay. Here, too, the general strike is west-north-west, nearly at right angles to that of the Arvali range, but the formation lies within the same area of azoic rocks, and so may yet admit of more exact affiliation. The following notice is extracted from the original Memoir on Western India [1]:—

"A small tract, about 30 miles east of Baroda, consists of beds which, although somewhat similar in general character and state of semi-metamorphism to the Bijáwars, differ so greatly in their mineral composition that it appears probable they must belong to a distinct group of rocks. They do not contain any of the rocks so characteristic of the Bijáwars, while their own marked beds are wanting in that series. It is by no means clear whether, if distinct, they are higher or lower in the general sequence; they vary greatly in the extent to which they are metamorphosed, and they are, in the area examined, entirely isolated; very probably they do not differ greatly in age from the Bijáwars.

[1] Mem., G. S. I., Vol. VI, p. 202.

"The area occupied by these beds extends for about 20 miles to the east from Powagarh hill, and for 7 or 8 miles to the south from Chámpanír, at the north-east base of the hill. To the north, they stretch for a considerable distance, but have not been examined. There is also a small tract of hilly country a few miles farther south, which appears to consist of them. As it does not appear at all certain whether they can be referred to any one of the systems of rocks hitherto described as intervening between the metamorphics and the Vindhyans in Central India, it appears best to give them a temporary and local name, and that of the old town of Chámpanír, the former capital of the Mahomedan kingdom of Guzerát, appears best suited for the purpose.

"The principal constituent rock of the Chámpanír beds is quartzite or quartzite-sandstone, very similar in character to rocks which occur both in the Bijáwars and the metamorphics. The other beds are mostly slates, conglomerates, and limestones, ferruginous bands occasionally occurring.[1] Some of the limestones are highly crystalline; in one place near Kadwál they were found to contain actinolite; in other places, as near Surájpur, they were quite unaltered. All the rocks susceptible of cleavage are highly cleaved, the planes striking about west 10°—20° north in general. Some of the slate appears to be so fissile that it might probably be made available for roofing.

"The conglomerates are perhaps the most distinctive beds in the group. They are well seen about Jhaban, on the road between Surájpur and Jambughora. The matrix is in general a coarse, gritty sandstone, containing pebbles and boulders often a foot in diameter, and occasionally more (one was measured which amounted to 3 feet), and consisting of granite, quartzite, talcose slate, and crystalline limestone. The talcose slate of which some of the pebbles are composed is scarcely more metamorphosed than the Chámpanír beds themselves. The quartzite boulders are the largest. The limestone pebbles are very numerous, and as they are dissolved away on the surface by exposure to the weather, the hollows which contained them remain empty, and give a peculiar vesicular appearance to the rock. Some of the limestones of the pebbles contain silicious laminæ, as in the limestones of the Bijáwars, but the rock in this case is more crystalline; it rather resembles the limestone in the metamorphics east of Kanás. The cleavage which is characteristic of the Chámpanír beds throughout, is frequently apparent in these pebbles, though it is but rarely distinguishable in the sandy matrix; none of the pebbles are typically Bijáwar.

[1] Some of these are a rich iron-ore, and occasionally they contain much manganese.

"At one place near Anandpur, the matrix of the conglomerate appears to be a perfect breccia, a mixture of angular fragments of black slaty silicious rock and coarse sandstone, both containing pebbles. This is near the junction of the conglomerate with slaty beds, the latter apparently the newer. The rocks appear to have been much crushed; they look as if angular fragments of slate had become mixed with sandstone, and then all re-consolidated. The granite and quartzite pebbles, however, exhibit no signs of any violence.

"Very little can be ascertained of the sequence of the beds. The slates, limestones, and quartzites of Surájpur are evidently high in the series; they appear to rest upon the conglomerates of Jhaban, and these again upon the quartzites of Narukot and Dandiapura. Judging from the extent of alteration, too, the Surájpur beds are high in the group; but no base is seen, unless the quartzites of the southern patch rest upon granite about Mankipur. These quartzites much resemble those of Narukot, &c.

"Reference has already been made to the apparent passage of Bijáwars into metamorphics; in the case of the Chámpanír beds, the appearances are much stronger, especially along the southern boundary; so much so, indeed, that it is frequently almost impossible to determine exactly where that boundary should be drawn. Within the tract occupied by the metamorphic rocks, quartzites which have in no way the appearance of outliers, occur in several places, as near Mirwania, and again west of Jambughora. In the latter case, a true conglomerate containing large rolled pebbles of quartzites, &c., and very similar to the conglomerate already described as occurring a little further to the north-west, within the Chámpanír area, is found amongst the metamorphic rocks. The same apparent passage occurs south of Surájpur, the Chámpanír beds being more crystalline near the boundary. There is, of course, the possibility of faults accounting to a great extent for the apparent passages, and when rocks do not differ greatly in mineral composition, apparent cases of transition are very likely to occur; but still there is, in places, an apparent gradual change, both along the line of strike and across it, from Chámpanír beds into metamorphics."

The Arvali proper.—A considerable area of the central Arvalis, north of Abu and Udepur (Oodeypoor), has been cursorily examined; we can at least indicate the main features of the ground and the points that most need elucidation.[1] South of Ajmir, the hills form a continuous range, having a width of about 30 miles, and including summits ranging

[1] The observations on this area are taken from reports by Mr. C. A. Hacket: Records, Vol. X, page 84, and map.

up to 4,200 feet in elevation. The range is composed of a series of ridges with deeply excavated valleys, having a steady strike to north-east-by-north. The watershed occurs in a central depression, from which the streams pass by narrow gorges through the ridges on each side. North of Ajmir, for nearly 100 miles, the continuation of the range consists of narrow and broken ridges of small elevation and separated from each other by several miles of alluvium. Further north, in Shaikhawati (Shekhawuttee), Alwar (Ulwur), and Beána, there are again some considerable groups of hills surrounded by alluvial deposits or blown sand.

It is only in the areas of more or less connected outcrops that there is any chance of working out the succession of the formations. In the central area, south of Ajmir, the lowest rocks, consisting largely of gneiss, are exposed; while in the smaller hills to the north the upper formations are almost exclusively found. This contrast is, to some extent, an effect of surface conditions, for it is plain, from the fringing outcrops of gneiss at the base of the northern hills, that the wide alluvium-covered areas here are for the most part formed of this rock.

In the Alwar hills, the Arvali series has been divided into the following groups:—

Mandan—slates, schists, quartzites.
Ajabgarh—slates, quartzites, breccia, limestone.
Alwar—quartzite, with subordinate bands of schist, conglomerate, and bedded trap.
Schist and limestone (Raiálo).
Quartzite (Raiálo).

The Mandan group is only known in isolated hills, as at Mandan, Tasing, and Barod, 25 miles north-west of Alwar; so that its position, and even its validity as a separate group, are somewhat doubtful. The Ajabgarh group is well exposed about the village of that name in the hills 25 miles south-west of Alwar, where its superposition to the Alwar quartzites is well seen. The Alwar group is by far the most important. It is locally divisible into several unconformable groups, having a great aggregate thickness; so that it is virtually a series rather than a group. In the southern part of the Alwar hills, the Raiálo limestone and quartzite form a doubtfully subordinate or affiliated member beneath the main mass of the Alwar quartzite, which elsewhere rests upon gneiss or passes into it.

The Beána hills (24 miles south-west of Bhartpur), 16 miles long by 10 broad, are formed altogether of the Alwar beds, which are here clearly divisible into five sub-groups, each many hundred feet in thickness, and more or less unconformable to each other; the unconformity being shown either by simple overlap, or by intervening denudation, or by stratification

in oblique contact showing intervening disturbance. The sub-divisions are named after the principal villages of the neighbourhood, as follows, in descending order:—

Weir—quartzites and black slaty shales.
Damdama—quartzites and conglomerate.
Beána—white quartzite and conglomerate.
Badalgarh—quartzite and shale.
Nithahár—quartzite and bedded trap.

It is possible that a very close examination might detect corresponding sub-divisions in the apparently continuous sequence of quartzites in the hills of Lálsot and Alwar. The bedded trap of the Nithahár group corresponds with that at the base of the Alwar quartzites on the south side of the Alwar hills, and it is again found on the same horizon, to the south, in the Rimtumbour hills. The Raiálo beds are not found in the Beána hills.

On the whole, the Arvali transition rocks are strongly metamorphic. The quartzites are commonly sub-vitreous, although sometimes still a free-stone, forming a very fine building material. The limestones are mostly in the condition of crystalline marble; and the schists, even of the Mandan group, often abound in crystals of andalusite, staurotide, and garnet. The conditions of disturbance correspond with those of mineralogical change; high dips and sharp flexures are the rule, flat undulations the exception.

It is in the relation of the Arvali series to other formations that the interest and the difficulty lie. Where first observed in the Alwar hills, the crystalline metamorphic rocks are badly exposed, and the Alwar quartzite seems locally to rest abruptly and unconformably upon a granitic gneiss, whereas elsewhere it passes downwards, by inter-stratification, into a well-foliated gneiss. Had these conflicting relations not been explained, we should have had to distinguish two gneissic formations within the area. From the examination of the Ajmir ground, however, where the base-rocks are exposed, it becomes evident that the supposed granitic gneiss of the Alwar hills is really intrusive granite, younger than the Alwar quartzite. The granite is most abundant along the axis of the range, on a line through Ajmir, Beáwar, and Tárágarh, being generally in the strike of the beds, but also cutting across them into the Alwar quartzites. In the Ajmir hills, there are also numerous sections showing the Alwar quartzite passing down into black gneissose mica-schists with crystalline limestone and schistose quartzites. These would answer approximately to the Raiálo beds of the Alwar hills, and they pass downwards into the gneiss; no separation being discernible. The gneissose Raiálo beds are

the prevailing rock in the Ajmir country, the limestone being very inconstant, even within short distances.

The Ajmir section would agree well enough with those in the Alwar hills, save for some still doubtful cases, where the Raiálo beds seem to be altogether wanting, and the Alwar quartzite is close to gneissic beds of a lower type, thus suggesting here a break in the series, which to the south is unbroken. This discrepancy of the sections at Ajmir and Alwar suggests an explanation of a difficulty that occurs in the Beána hills, about Nithahár, where the bottom band of the Alwar group (the Nithahár quartzites and bedded trap) is found resting on the edges of vertical schists and thin quartzites, no other supporting rocks being exposed in this neighbourhood. It has been stated above how in the Beána hills the several sub-divisions of the Alwar group are more or less unconformable to each other, involving intervening disturbance and considerable denudation, whilst corresponding breaks are only suggested in the Alwar hills by the occasional presence of conglomerate bands. In the Ajmir country, even this evidence of intervals between the groups is not found. It would, however, be a stretch of stratigraphical rules to look upon such total unconformity as that of the Nithahár beds on the schists as a mere local break, and to admit these schists into the Arvali series. According to ordinary practice, these schists would be considered older than the gneiss, with which the same Alwar quartzites are in conformable sequence at no great distance (30 miles). This would, however, be a still more anomalous position to take up ; so we are forced to find a horizon for these slaty schists of Nithahár between the trappean zone of the Alwar quartzites and the bottom gneiss. Perhaps, the least forced view to adopt is that they represent the Raiálo beds;[1] in which case these can scarcely be kept in the Arvali series, which would then end (downwards) with the Alwar quartzites. The trappean beds at the base of the Alwar group in the northern hills are not found south of Ajmir.

The relation of the Arvali series to younger formations is also not free from doubt. The boundary of the adjoining Vindhyan basin is for the most part a straight fault-line, running north-east to south-west, parallel with the strike of the older formation; but south-west of Karauli there are some outliers of the Vindhyans resting, with more or less of unconformity, on Ajabgarh beds of the Arvali series. The puzzle occurs in a broken ridge, running close to, and parallel with, the Vindhyan boundary through Hindon, and reaching on the north-east to within 3 miles of the Beána hills. This ridge is mostly formed of well-characterised Gwalior rocks (the ferruginous banded jasper beds), which are placed in our

[1] This is at present Mr. Hacket's view of the case.

upper transition series, as explained elsewhere. Here they are highly disturbed, but not more altered than the Arvalis of the Beána hills. Were these rocks of the Hindon ridge quite isolated, one would scarcely hesitate, from the general conditions of the formations concerned, to place the Gwaliors higher than the Arvalis, the contrast between the composition of the two groups in close proximity forbidding their being identified with each other. But, with the Gwalior jasper beds, there are remnants of a distinct and overlying formation consisting of quartzite sandstone with some red and black slaty shales and irregular bands of limestone. These also are nearly vertical, and roughly parallel to the jasper beds, but certainly unconformable to them. The mechanical relation (parallel unconformity and parity of disturbance) would answer well for that between the Vindhyans and the Gwaliors in the standard area, 70 miles to the south-east across the Vindhyan basin; but these upper beds of the Hindon ridge are much more like to some in the Arvali series than they are to any in the adjoining Vindhyans. In the Alwar conglomerates of the Beána hills, moreover, pebbles have been observed very like the Gwalior jasper. It is agreed, however, for the present to overlook these objections, and to consider these upper beds to be Vindhyan, in view of the more difficult alternative of introducing the whole Arvali series between the Vindhyans and the Gwaliors; and of finding a place for the Gwaliors, as well as for the Nithahár schists, between the Arvalis and the gneiss.[1] The absence of any representative of the Gwaliors between the Vindhyans and the Arvalis in the adjoining ground, south-west of Karauli, is another obstacle to the interpretation proposed.

The many narrow ridges stretching from the south-west into the plains at Delhi and to the west in Hissar, are probably formed of some group or other of the Arvali series. They all have a core of quartzite with more or less vertical bedding, and the associated rocks, as far as they are exposed on the flanks of the ridges, indicate advanced metamorphism. The well-known "flexible sandstone" of Kariána, 60 miles due west of Delhi, occurs in one of these outliers of the Arvalis; it is a locally decomposed condition of a band of gneissose quartzite that is much quarried for quernstones (hand-mills).

Korana hills.—Far to the north-west of the Hissar country, after a wide interval of plains, traversed by the Sutlej and the Rávi, some hills occur on both sides of the Chenáb, at Cheniot and Korána. These hills, to which reference was made a few pages back, are only 40 miles distant from

[1] Mr. Hacket suggests that there may be inversion in the Hindon ridge, whereby the apparently upper rocks (now supposed to be the Vindhyans) may really be the older, and thus presumably Arvalis.

the Salt Range, but the rocks are totally different from any that occur there, and correspond well with the character of the transition rocks of the Arvali series. They consist of strong quartzites, with associated clay slates, forming steep ridges with a north-east to south-west strike. The highest summit is stated by Dr. Fleming to be 957 feet above the plain. The rocks here seem, from the uncertain observations given of them, to be in a less metamorphic state than those nearest them to the south-east—a fact which agrees with their remoteness from what is presumably the centre of disturbance of the region. The oldest rocks of the Salt Range are probably (from their contrasting petrological conditions) very much younger than the strata of Koràna; and as the former are at least Silurian, and probably older (the only Silurian fossils being found in a group some distance above the bottom beds) we obtain a small hint upon the age of these transition deposits.

Malani beds.—In the south-west quarter of the Arvali region we may perhaps rank with the lower transition series the peculiar eruptive rocks described as the Maláni beds, as follows[1]:—

It is evident that these, the oldest rocks met with in the portion of the desert traversed, are volcanic. Their extremely silicious nature may be due to alteration, but their porphyritic character, and the occasional occurrence of ash beds, sufficiently attest their volcanic origin. They consist principally of very silicious felsites, so hard that they are not scratched by quartz, and have frequently the appearance and texture of jasper. They vary greatly in colour, from black or dark brown to pink, blue or white, the dark-coloured rock being always hard and undecomposed, whilst the light-coloured varieties are softer and appear to be altered. The most constant character is the presence of small crystals of felspar, usually of a pink or red colour, in addition to which small grains of transparent silica are frequently disseminated throughout the rock.

In places diorite was found associated with these rocks, and in some of the hills west of Bálmir, coarsely crystalline granitoid syenite and pegmatite are intercalated in large masses with the porphyritic felsites. True granite may occur, but in the few hills examined mica was absent, although the character of the rock was distinctly granitic. The presence of similar granitoid rocks elsewhere is rendered probable by the occurrence of pebbles and boulders in some of the later formations.

[1] Records, G. S. I., Vol. X., p. 17, 1877. The portion of the desert traversed was that in the neighbourhood of the road from Umarkot to Jodhpúr *viâ* Bálmir, and from Jodhpúr to Rohri *viâ* Jesulmir. The name Maláni is that of a large district belonging to Jodhpúr; the principal town is Bálmir.

The Maláni rocks must be very ancient, but no idea can be formed of their geological position, as they are nowhere associated with rocks of known age except where underlying beds of comparatively recent date, and nothing resembling them appears hitherto to have been detected elsewhere in India. They form the hills extending upwards of 30 miles west of Bálmir, and south as far as Chotan, 25 miles south-west of Bálmir, and north probably to Vinjorai, 35 miles south-south-east of Jesalmir. South of the Bálmir hills, no rocks are known to occur for a considerable distance, but the syenite hills of Nagar Párkar, which are in this direction, may probably belong to the Maláni series. To the eastward of Bálmir, no rocks are seen for 30 miles, but the prophyritic felsites are extensively developed on the Lúni river for many miles below Jasol and Pánchbhadra; they appear to form a portion at least of the high hills south-west of Jasol, towards Jallor; they constitute the few rocky hills which rise out of the sandy plain between Pánchbhadra and Jodhpúr, and they re-appear at Jodhpúr itself, where some of the beds are unmistakable volcanic ash. On the road from Jodhpúr to Jesalmir, their presence, except near Jodhpúr, was only detected in the neighbourhood of Pokran.

CHAPTER III.

PENINSULAR AREA.

TRANSITION OR SUB-METAMORPHIC ROCKS, UPPER SERIES.

General characters — Gwalior area — Kadapah area — Paupugni group — Cheyair group — Nallamale group — Krishna group — Kaladgi area.

General characters.—It has been already explained that the division of the transition system into an upper and a lower series has been adopted, to a great extent, as a matter of convenience, in order to mark common characters of likeness in some of the many separate rock-basins, and for the purpose of indicating a possible distinction in age between the two divisions. The extremes of the whole series are well marked; on the one side by a close relationship to the adjoining metamorphic rocks, as in Behár, on the other by a total severance from them, as in the Gwalior basin. This character would be an absolute distinction if it were certain that the crystalline rocks were of the same age throughout; but it has been shown that on opposite sides of the Bijáwar basin the same transition beds are in total contrast with the gneiss of Bundelkhand, while they are intimately connected with crystalline rocks in the Son valley. The difficulty in comparing the relations of detached basins of transition strata might be got over if there were any really independent criterion of the relative ages of crystalline metamorphic rocks; but there is no prospect of such a test being available, and to approach a solution by way of detailed work in the field and the laboratory would be an extremely tedious and difficult undertaking. We can thus for the present only suggest a tentative grouping of these rocks, as lower and upper transition: the former, as has already been mentioned, being those that exhibit commonly or frequently an advanced state of disturbance and metamorphism with intimate or doubtful relations to the gneissic rocks; the latter, those that are comparatively little affected by metamorphism, and are quite separate from the contiguous gneiss.

These difficulties and compromises are well illustrated in the Bundelkhand region. On opposite sides of the area, more than 100 miles apart, the Bijáwar and the Gwalior formations rest horizontally or with a gentle slope upon the gneiss, in precisely the same mechanical relation.

The denuded outcrops of the quartz-reefs traversing the gneiss are in both cases covered by the bottom deposits of the overlying transition groups. A slight difference is noticeable at the actual contact; the bottom layer of the Bijáwars is commonly more or less adherent to the gneiss, the result of the partial metamorphism that the Bijáwars, even in Bundelkhand, have undergone; whereas in the Gwalior rocks the purely mechanical texture is still unaffected in the bottom contact-layer. But this difference could count for nothing at so great a distance.

A general list of the rocks of the Gwalior formation would not suggest any separation from the Bijáwars. Each contains sandstone or quartzite, limestone, jasper, and iron bands and bedded traps. The arrangement of these different strata is, however, markedly different in the two cases; and the general facies of these two series does not suggest to the observer that they are representative. Still the Gwaliors are rather more nearly allied by mineral characters to the Bijáwars than to the lower Vindhyans, and on this account the Gwaliors are placed in the intermediate, or transition, rather than in the upper series of azoic formations. The unconformity of the upper Vindhyans upon the Gwaliors is, moreover, of a very marked character: at Ládera (16 miles south-east of Gwalior), Vindhyan sandstone rests upon the gneiss at a lower level than the bottom Gwaliors in the scarp close by.

Three widely separated basins have been classed as upper transition rocks: that of Gwalior in Northern India; that of Kadapah in the North Karnatic region; and that of Kaladgi in the South Mahratta country.

Gwalior area.—The Gwalior area is the smallest of the three, being only 50 miles long, from east to west, and about 15 miles wide.[1] It takes its name from the city of Gwalior, which stands upon it, surrounding the famous fort built upon a scarped outlier of Vindhyan sandstone, which rests on a base of massive bedded trap belonging to the transition period. The composition of the Gwalior formation is very mixed, and admits of only a two-fold and very unequal sub-division. There is constantly at the base a sandstone or semi-quartzite, called the Pár sandstone, from a town 12 miles south-west of Gwalior, a fine-grained stone, pale grey in colour, regularly and thinly bedded. It varies from 20 to 200 feet in thickness, and is overlaid by about 2,000 feet of strata consisting mainly of thin flaggy silicious or ferruginous shales copiously interbanded with hornstone and jasper, both

[1] There is a short notice of the Gwalior formation by Mr. C. A. Hacket, in the Records, Geological Survey of India, Vol. III, page 33. It is also mentioned in Mr. Hacket's paper on the North-East Arvali region: Records, Geological Survey of India, Vol. X, page 84, with a sketch map.

finely bedded and concretionary. The jasper is frequently of a brilliant red colour. Limestone, more or less cherty, occurs on two principal horizons in these shales, but not continuously; and there are two principal zones of a dense basic dioritic trap. All these upper beds, constituting the bulk and the characteristic portion of the Gwalior formation, have been distinguished from the Pár sandstone as the Morár group, the name being taken from the military station close to Gwalior.

With the exception of some very local slips and crushing, the Gwalior rocks are undisturbed, having a steady low northerly inclination of only 3° to 5°. The features of the area correspond with this arrangement of the rocks. There is a continuous broad plateau-range on the south, from 300 to 500 feet high, formed largely of the Pár sandstone. On the west it is connected at right angles with the Vindhyan scarp, which lies at a slightly lower level; and it stretches thence eastwards to the Sindh river, forming a steep scarp to the south overlooking the gneissic area of lower Bundelkhand. There are two other ranges parallel to the Pár scarp on the north, but they are much broken by cross-drainage. The two longitudinal valleys between the three ridges are due to the greater decomposition and erosion along the two outcrops of bedded trap. It is only at the west end, near the Vindhyan plateau, that these trappean bands are well exposed.

With one exception at the west end, where the Paniár stream breaks through to the south, the Pár scarp forms a watershed. The general easterly direction of the scarp is very steady up to the Sindh river, but the line is much serrated by bays and headlands, in which the nature of the junction with the gneiss is well exhibited. At the most advanced points of the range the gneiss reaches to within a few feet of the summit, with only a thin capping of the sandstone, but as we follow the junction northwards into the valleys it gradually falls to the lowest level. A further study of the section shows that this slope of the junction is aboriginal, and not due to a tilt of the ground since the formation of the Gwalior deposits. Close to the edge of the scarp near Pár an outlier of the Morár shale series has been largely worked for iron, and here the Pár sandstone is only about 20 feet thick. Nothing like unconformity has been detected between the Morár and the Pár beds, so that this must be taken as the original thickness of the lower band in this position. On the north side of the range, however, wherever sections are exposed, as about Badháno (10 miles south-east of Morár) the thickness is greatly increased. We may take 200 feet as a minimum, the whole not being seen. In this position, to the east, shales are found intercalated with the sandstone, showing the close connexion of the two groups. These

facts would tend to prove that to some extent the position of the Pár scarp was a limit of deposition in the Gwalior period. The very bottom layer is often conglomeratic.

On the top of the Pár sandstone there occurs locally a compact calcareo-silicious bed that is worth noticing, because the peculiar coralloid forms it exposes by weathering were thought by Dr. Stoliczka to be of organic origin. This rock is best seen just south of Bára, 25 miles east-by-south of Morár.

The lower zone of bedded trap is about 400 feet from the base of the Morár group. There are two or more flows, with intervening shales. They are well seen near the villages of Bela, Chaura, Paniár, and Bárai, on both sides of the Indore road, at from 6 to 10 miles south-west of Gwalior. The thickness of these flows is very various; from 70 feet they thin out to nothing, but are probably nowhere absent on this horizon, obscure outcrops of them having been observed at several places in the valley formed along their strike to the east. At some spots there is an appearance of the trap having burst up through the underlying shales: thus in the stream near the trunk-road north-west of Bela there is a low section showing the shales and trap in vertical contact; but otherwise the interstratification is unbroken.

In connexion with this lower zone of trap there occurs a rock that will again come under notice in these formations and also in the lower Vindhyans. It is a compact porcellanic rock, as sharply and regularly bedded as the associated jaspideous shales. Occasionally it is obscurely porphyritic, having small indeterminate crystals scattered through it. An analysis of a specimen from the Gwalior beds gave the following:—

Silica	60·50
Alumina with a little iron	24·51
Lime	2·08
Magnesia	1·32
Potash	9·16
Soda	4·51

This approaches to the composition of orthoclase felspar. But there is no presumption that this porcellanic rock has any connection with eruptive phenomena, and its association here with trappean beds of highly basic composition, is probably quite fortuitous, for in the lower Vindhyans, where the porcellanic and porphyritoid beds are much more developed, there is no eruptive rock whatever.

The upper zone of trap is on a much larger scale. The whole plain of Morár is underlaid by it, at least on the north side; and if allowance

is made for the small dip, the flow can hardly be less than 500 feet thick. It is admirably exposed in the under-cliff of the Vindhyan scarp in the fort hill and the promontories to the westward. In a small plateau about 3 miles to north-north-east of the fort it is overlaid horizontally by typical, rusty, jaspideous shales of the Gwalior formation. Several detached hills in the plain lying east-by-north of Morár are formed entirely of this massive trap.

Limestone occurs principally on two horizons, in and above the lower trappean zone, and in the northern hills above the great trap-flow. In both positions it is very uncertain and discontinuous. Within a space of 100 yards a mass of limestone more than 50 feet thick is found to be totally replaced by ochreous shales.

The iron ore which is largely mined in the Gwalior formation is quite different from that found in the Bijáwars. The latter is a massive concretionary hæmatite irregularly concentrated in ferruginous earthy sandstones. The Gwalior ore is a fine wafer-like shale composed of thin flakes of hæmatite, with still thinner films of clay. It is a decomposed condition of the jaspideous shales. The amorphous silica has been dissolved out, leaving the iron ingredient in a very favourable state for mining and smelting. The conditions for this change seem only to have obtained near the base of the formation. All the mines are in the shales a few feet over the Pár sandstone.

To the east and north the Gwalior formation is covered by the great alluvial plains; on the west it passes under the upper Vindhyans; and two inliers, exposed by the removal of these covering rocks, are crossed by the trunk-road. The only specific identification of the Gwalior beds beyond this standard area has been already noticed in the concluding portion of the last chapter. The spot is at the nearest point on the opposite side of this northern extension of the Vindhyan basin, 70 miles to the north-west of Gwalior: at Hindon there is a narrow ridge of banded jasper and ferruginous shales which Mr. Hacket considers to be undoubtedly Gwaliors, the conjecture being much supported by the fact that no similar rock, with which they could be confounded, occurs in the Arvali series of neighbouring areas. The Gwaliors at Hindon are more or less vertical; and in contact with them, but not conformably, are some quartzite-sandstone and red and black slaty shales with irregular bands of limestone. By position these beds should be of later origin than the Gwaliors, and on this account Mr. Hacket thinks they must be Vindhyan, although specifically they are in some respects more like rocks of the Arvali series.

The Kadapah area.—The Kadapah formation of upper transition rocks occupies a large area about the middle of the east side of the peninsula, where the coast-line bends from a northerly to a north-easterly direction. This feature has probably a remote connexion with the form of the Kadapah basin, which is roughly of a crescent shape, convex to the west. The north-east horn of the crescent is known as the Palnád, and reaches to Juggiapet, a few miles north of the Krishna river; the southern termination at Tripeti hill is 30 miles north-west of Madras, or only 18 if measured to the outlier at Nagari Nose. The town of Kadapah (Cuddapah) stands in a south-central position near the Pennair river. Gúti (Gooty) is just outside the western border at its centre, and Karnul more to the north, on the Tungabudra, a few miles above the confluence with the Krishna. The length of the basin is about 210 miles and its width 95, the area being nearly 13,500 square miles.

The eastern edge of the basin constitutes a well-defined segment of that vaguely expressed general feature known as the Eastern Ghâts. Locally, the actual face of the highlands is here known as the Yellaconda ridge. It is a flanking member of the Nallamale range, which is formed by a belt of contortion of the Kadapah rocks along this side of their basin. Between the hills and the sea there is a zone of low country, formed of metamorphic rocks and alluvium, about 50 miles wide, constituting the plains of the Karnatic, or Payen Ghât (country below the Ghâts), in the Guntur, Nellore, and North Arcot districts. The elevation of this ground at the base of the hills is under 200 feet, the crest of the Yellaconda rising to about 1,000, and the summits of the Nallamale to 3,500. The centre of the Kadapah basin is occupied by the broad valley of the Khundair, the rocks rising again to form a steep range (locally 2,000 feet above the sea) along the western margin of the basin, overlooking the gneissic upland of Maisur (Mysore) and Bellari, the elevation of which near the range varies from 800 to 1,800 feet according to the position with reference to drainage. The Madras Railway enters the basin at Gúti, and leaves it at the southern point of the crescent, while the Krishna river adopts a very similar course in the northern limb. The watershed of the basin lies far to the north, and the Pennair receives most of the drainage.

More than a third of the area within the boundaries indicated is taken up by the overlying Karnul formation (to be described in the next chapter), which occupies all the low ground of the Khundair valley in the middle of the basin, and another large space in the Palnád. In thickness they are very inferior to the Kadapahs. There

is, no doubt, marked unconformity between the two, but not much more than exists between the several divisions of the Kadapah series, and both have undergone nearly equal disturbance and metamorphism, so that it is rather awkward to draw one of the main divisions of our azoic series between them. It has been already explained that these divisions are to a great extent arbitrary. A difficulty of this kind is always sure to occur in attempting to apply a strict classification over a large area.

The Kadapah formation has been divided into the following groups in descending order[1] :—

Krishna group, 2,000 feet	Quartzites (Srishalum). Slates (Kolumnullah). Quartzites (Irlaconda).
Nallamale group, 3,400 feet . . .	Slates (Cumbum). Quartzites (Byrenconda).
Cheyair group, 10,500 feet	Slates (Pulumpet). Quartzites (Nagari).
Paupugni group, 4,500 feet . . .	Slates (Vaimpulli). Quartzites (Gulcheru).

The distribution of these groups relieves us in some measure of the enormous aggregate thickness of 20,000 feet given in this list. Although in order of time the succession may be taken strictly, it is scarcely to be supposed that there was ever at one spot a continuous superposition of these strata to the extent of their aggregate thickness. The exposed outcrops, at least, do not support such a view; even within the present rock-basin, which must be taken as only a part of the area of deposition, the groups are local and discontinuous, each in turn overlapping the one below it, and resting on the gneiss. In each case, however, there is more or less of denudation-unconformity as well as overlap; so that the groups are much more than mere horizons of variation in deposition.

The original characters of deposition and the induced characters of disturbance are closely related to the actual boundaries of the field. All round the western boundary the junction is natural, *i. e.*, the deposits rest as originally deposited upon the gneiss, the strata having undergone comparatively little disturbance. On the east side of the basin, on the contrary, there has been much contortion of the strata; the boundary is represented as faulted and the beds often inverted, generally presenting the appearance of a band of quartzite dipping steeply towards the gneiss. The lower groups are found to the south-west, and are gradually overlapped to the north and east.

[1] There is a map and description of the Kadapah formation by Mr. King in the Memoirs, G. S. I., Vol. VIII, Part I.

Paupugni group.—In each of the groups of the Kadapah series, sandstones or quartzites prevail at the base, and earthy deposits forming shales or slates above, limestones often occurring with the latter. The Paupugni group is only found between the Tungabudra and the Cheyair, being overlapped in both directions by the Cheyair beds. It takes its name from the river, in the gorge of which the best sections are seen. Its bottom member, the Gulcheru quartzites, rest upon an uneven surface of the gneiss, and rise up to the west to form steep cliffs over an undercliff of the crystalline rock, as over Gulcheru (15 miles south-south-west of Kadapah). Although the contact is quite sharp, the two rocks are often connected together into an adhering mass. A considerable thickness at the base is coarsely conglomeratic, the pebbles consisting of the brecciated veinstones and banded jasper-rocks which form prominent outcrops in the adjoining metamorphic area. These bottom beds are described as shore-deposits.

In the overlying Vaimpulli sub-division of the Paupugni group, limestone is largely associated with the shales, and intrusive sheets of trap are also of frequent occurrence. In contact with or near the trap, the limestone often contains bands of serpentine and steatite, as may be seen close to Karnul, where the Vaimpulli band has overlapped the bottom sandstones, and rests directly on the gneiss. Vaimpulli is a village 30 miles west-south-west of Kadapah.

Cheyair group—The Cheyair group is well exposed on the Cheyair river. It is divided into two areas by the Karnul formation stretching southwards, west of Kadapah, into contact with the Paupugni rocks. The constitution and relation of the Cheyair group in the two positions are somewhat different. In the north-west area, traversed by the Pennair, the bottom band of sandstones and conglomerates is comparatively unimportant. It is there described as the Pulavaindla sub-division, from a town 40 miles west-by-south of Kadapah. North of the Krishna it overlaps the Vaimpullis, and in the Pennair ground it rests upon their denuded surface, the conglomerates and breccias being largely made up of the characteristic chert-bands of the Vaimpulli limestone. Here, too, intrusive sheets of trap occur in the Pulavaindla band. The corresponding beds in the southern area are described as the Nagari quartzites, from the well-known hill near Madras. They form for the most part in this region the bottom-rock of the Kadapahs, resting on the gneiss. The conglomerates here are made up of pebbles of quartz and quartzites (which are themselves sometimes conglomeratic), and occasionally of red-banded jasper, being thus more like the Gulcheru beds of the Pennair area.

The upper band of the Cheyair group is described in the Pennair area as the Todapurti beds, named from a principal village of the district. They comprise a great series of slaty shales with limestones and eruptive rocks, both intrusive and cotemporaneous, ferruginous chert and jasper beds. The shales predominate; although not greatly disturbed, they are to some extent affected by cleavage, and are hence qualified as slaty. Limestone occurs in two principal bands. It is a finely crystalline grey rock, with much segregated chert, which often assumes very fantastic shapes, especially in the upper part of the beds and near trap-flows. Of these eruptive rocks there are many strong outcrops, in two principal bands, a main one near the base of the group, and another two-thirds up. The only rocks that can be certainly classed as eruptive are coarse-grained, dark, basic diorites, sometimes compact and of grey or pale-green colours. They are shown to be cotemporaneous by their outcrop being continuous for long distances between well-marked bands of aqueous deposits. But frequently the intervening deposits cease, and the flows coalesce; locally, moreover, they are distinctly confluent with intrusive dykes, as is well seen in the small bay below the southern flanks of the Opalpád plateau, 20 miles east of Gúti. Perhaps the strongest argument for the contemporaneity of the bedded traps on this horizon is the fact that no intrusive igneous rock is known to occur higher in the formation, or in the Karnuls, and this could hardly be the case if the massive bands in the Todapurti zone were intruded after the completion of the sedimentary series.

It is in this group, and in the zone with the trap, that representatives occur of the porcellanic beds described in the Gwalior formation. Their presence, as distinctly bedded rocks of quasi-igneous character, and the occurrence of the undoubtedly igneous rocks in a stratified condition, have certainly influenced the argument in favour of the eruptive (volcanic) origin of both. The flaky granulated varieties are taken to be ash-beds, and the compact form is spoken of as felsite. There are, however, great difficulties opposed to the adoption of this view. These highly silicious beds would be of the very opposite type of volcanic products from the real igneous rocks with which they would thus be connected. Silicious lavas are the least prone to assume a finely stratified condition, whereas these beds are quite remarkable for their continuity in thin, sharply defined beds; so that it is very difficult to conceive that they were originally fused rock. It would not be easy to imagine that explosive ejections, alternating with eruptions of basic rock, could be so exclusively of the felspathic type; and it appears probable that any connexion of these porcellanic beds with igneous rocks can only be through the remote and

collateral effects of eruptive action, such as mineral waters. It has been already stated that similar porcellanic beds occur extensively and typically in the lower Vindhyan formation, in which no eruptive rock is found.

In the Cheyair area, the Palumpet slates and limestones represent the Todapurti beds of the Pennair. The traps and porcellanic beds are absent. The limestones are again silicious, and sometimes they are brecciated in a very unaccountable manner, without any disturbance of the strata. Some beds present a rugged humpy surface, suggestive of a coralline formation, but no organic structure has been detected.

Nallamale group.—The Nallamale occupies a larger area than the other groups, principally on the east side of the basin, and takes its name from the mountain range. The Byrenconda summit, 3,500 feet above the sea, gives its name to the bottom band of quartzites. In the Pollconda range, east of Kadapah, these quartzites rest with slight unconformity upon the Cheyair group. In the Pennair area, the strong quartzites of the Gundicotta hills overlying the Todapurti shales are on the same horizon. Here the beds have a gentle northeasterly slope and pass under the Karnul formation, but when they rise again to the east, in the Nallamale, contortion is the rule, often to so extreme a degree as to produce folded flexures and inversion. In the synclinal troughs of these contortions the upper member of the group is found, called the Cumbum slates, the underlying quartzites rising up to form the ridges.

The Cumbum slates are by far the thickest member of the group, and cover the greater part of the area. They are not very uniform in composition. There are several subordinate bands of quartzite, which it is not easy in broken ground to distinguish from the underlying Byrenconda rock, and the slates themselves present many varieties,—from fine, silvery, talcose beds, to coarse, earthy clay-slates of many shades of colour. Occasionally they are foliated and schistose, and not easily distinguished from the schistose beds of the adjoining gneissic area, when the two happen to come in contact; but, as a rule, quartzites are found at the junction. Strong bands of limestone are frequent in the Cumbum slates. The old lead mines near Nundialumpet, 16 miles north of Kadapah, occur in a dark silicious variety of this rock. Generally, it is compact or finely crystalline, micaceous or talcose, of a slate-grey colour with purple tinges.

At the north end of the Nallamale, just south of the Karnul and Guntur road, there is a great dome-shaped mountain known as Eshwaracupum. It is composed of lower Kadapah rocks dipping away from the hill on all sides, and surrounded by Nallamale beds. A

great thickness of strata is exposed, but it is not easy to identify them specifically with the groups already described.

Krishna group.—The fact mentioned, that strong bands of quartzite occur subordinate to the Cumbum slates, introduces much difficulty into the attempt to distinguish a higher group. Thus several ridges within the area of the Nallamale group are thought to belong to an upper independent group. The rock forming the Yellaconda range at the edge of the basin affords an instance. The range is formed to the south of strong, fine, white quartzite, and the Cumbum slates dip under this, whereas on the north the same slates rest upon the quartzites of the ridge which are supposed to be Byrencondas, the ridge itself being continuous throughout. Two solutions have been offered of this puzzle:—that in the southern part of the range the quartzites are inverted, being really the same band throughout; or, that an oblique fault, south-south-east of Gidalur, has brought in an upper quartzite to the south. The fact of the outcrops of such widely different horizons being so continuous, is a great difficulty to this supposition. The question is just mentioned here to indicate the complexities introduced by disturbance in this part of the Kadapah basin.

There seems, however, good reason to suppose that the plateau through which the Krishna has cut its gorge, and which is known as the Krishna Nallamale, is formed of beds higher than the Nallamale group and unconformable to it. These beds are therefore distinguished as the Krishna group. They comprise three well-marked divisions: The Irlaconda quartzities, forming the plateau of that name on the west, where they are 1,200 feet thick; the Shrishallum quartzites, forming a higher plateau to the north and east, called after a well-known shrine on the Krishna; and the intermediate shales, which are called Kolumnullah, after a stream that traverses them. To the north the group spreads out over a flat surface of gneiss, and to the east it passes under the Karnul beds of the Palnád, in which region, again, the rocks on the east are intensely disturbed.

The Kaladgi area.—In the South Máhratta country, on the southern border of the great area occupied by the Deccan trap, and in great part separating the trap-region from the gneissic area of Maisur, there are two basins of somewhat similar formations. This peculiar position is in a manner accidental, for it is certain that the trap once overspread the whole of these basins: along the crest of the Sahyádri it still stretches continuously for some distance to the south of them, and elsewhere outliers of trap are found beyond them resting on the

gneiss. The strata of both basins rest with total unconformity on the crystallines and are quite unaffected by metamorphism. Notwithstanding these similarities of condition, the rocks of the two areas are of different ages, and are considered to be respectively representatives of the Kadapah and Karnul formations, already noticed as occupying a common basin on the east side of the peninsula. In the South Máhratta country the two basins are only 8 miles apart at the Krishna, where the gneiss passes between them and then expands so as to be in contact with the trap for a length of 30 miles. Each basin is more than 100 miles in length, yet no remnant of either formation is found within the limits of the other, so that their separation rests upon collateral petrological evidence, both being totally unfossiliferous. The difference of age between the rocks of the two areas being presumed on the grounds of persistent lithological contrast and the analogy with other deposits elsewhere distinguished by superposition, this isolation in space is strongly suggestive of the supposition that the basins are approximately original, and not remnants of deposits formerly of wide extent. The eastern area is called the Bhima basin, from the large river crossing it centrally; the western is called after the town of Kaladgi on the Gatparba river, and geologically in the centre of the basin, although superficially near its eastern end. The rocks of the Bhima basin are affiliated to those of Karnul, and therefore belong to the lower Vindhyan horizon; while the Kaladgi deposits are ranked with the Kadapah rocks, and so come amongst the upper transition formations of our present provisional grouping.[1]

From the Krishna below its confluence within the Gatparba, the Kaladgi rocks stretch continuously westward for more than 100 miles and then disappear under the trap forming the crest of the Sahyádri. In this direction several inliers are exposed by the local removal of the basaltic covering; the largest, that at the foot of the Phonda Ghât, in the Konkan, is probably continuous with the main basin. On the north there is a large inlier at Jamkhandi. In all of these inliers, however, only the lower beds occur, so it is probable that the formation does not extend far beneath the trap. On the south borders of the basin there are numerous outliers of the bottom quartzites resting on the gneiss, both on the uplands of the Deccan and in the Konkan. The Vingorla rocks and other small islands off the coast all consist of the very hard rocks belonging to the quartzite series. The former continuity of all these patches of rock cannot by

[1] There is an excellent account of the Bhima and Kaladgi rocks in Mr. R. B. Foote's Memoir on the South Máhratta country: Memoirs, G. S. I., Vol. XII, 1876.

any means be asserted, for it is evident that the deposits took place upon a very uneven surface of the crystallines, of which there are extensive inliers within the main basin, as at Gokák.

The total thickness of the Kaladgi rocks is very considerable. They are divisible as follows:—

Upper Kaladgi.

	Thickness.
6. Shales, limestones, and hæmatite-schists	2,000
5. Quartzites, local conglomerates, and breccias	1,200—1,800

Lower Kaladgi.

4. Limestones, clays, and shales	5,000—6,000
3. Sandstones and shales	3,000—5,000
2. Silicious limestones, hornstones, or cherty breccias	
1. Quartzites, conglomerates, and sandstones	

The bottom conglomeratic rocks are made up of the adjoining crystallines, and vary with the composition of the latter. They generally slope up towards the boundary of the area and form a scarp over a basement of gneiss. The cherty breccias form the most peculiar and conspicuous member of this part of the series. Mr. Foote suggests, with much probability, that they are formed by the decomposition and crushing of the highly silicious limestones that occur on the same horizon. A large proportion of the total area, forming a continuous margin to the basin, very wide on the south, and including all the outliers, is formed of the lower members (Nos. 1, 2, 3) of the series, and in this position the rocks are very little disturbed, and scarcely at all altered.

The limestones and shales forming the 4th division of the Kaladgi series are only found in a special basin of depression and contortion on the north-east side of the area. They generally occupy low ground and are much concealed, but may be fairly seen about the town of Kaladgi, exhibiting much disturbance. Several varieties of the rock are very homogeneous in texture and variously tinted, making pretty marble.

The only remnants of the upper Kaladgi group are found in axes of synclinal flexures within this special basin, their preservation being evidently due to their being thus let in and encased by the folding of the whole series. Thus the maximum of disturbance and of metamorphism is exhibited in these remains of the topmost beds of the formation. The principal of these elliptical synclinal areas of the upper groups are those of Anathilli, Shimakeri, Lokapur, and Yenktapur, all within a short distance of Kaladgi. The direction of the axes of disturbance is very steady to between west by north and west-north-west. This is also the direction of the major axis of the basin itself, in which

all the special contortion seems to have been concentrated on the north side, along what is now the lower valley of the Gatparba.

Only four cases of intrusive rock have been observed in the Kaladgi area, and all in the region of disturbance, in the highest beds; three in the Lokapur basin, and one in the Arakeri synclinal valley. They are of compact, green diorite, unlike the older diorites of the gneissic area.

CHAPTER IV.

PENINSULAR.

VINDHYAN SERIES.

General Remarks — Lower Vindhyans, Karnul area — Palnád area — Bhima area — Godávari and Máhánadi areas — Son area — Bundelkhand area. Upper Vindhyans — The Son-Máhánadi boundary — Boundary in Bundelkhand — Boundary on the Ganges — Arvali boundary — Petrology — Relation to lower Vindhyans — Disturbance of the upper Vindhyans — Diamonds — Outliers.

General Remarks.—Vindhyan is one of the oldest names introduced by the Geological Survey. It was originally used to designate the great sandstone formation of Bundelkhand and Malwa, and it was adopted from the name currently applied by Anglo-Indian geographers to the scarped range composed of this formation along the north side of the Narbada valley. The vernacular signification of the term Vindhya is vague, the name being applied generally to the various ranges of hills which divide Hindustan proper, or the Indo-Gangetic plains, from the Deccan, and being quite as often employed for the hills south of the Narbada river, now commonly known to geographers as the Sátpúra, as for the northern range, to which, for the sake of avoiding ambiguity, the name Vindhya is now generally restricted. The Vindhyan formation was thus at first employed as a collective term for the beds in the great rock-basin, stretching in an east and west direction from Sasseram to Nimach (Neemuch), a distance of 600 miles, and from north to south for 300 miles, from Agra to Hoshangabad.

Throughout the greater part of their border, the Vindhyan sandstones are unconformably related to transition or gneissic rocks; but in the eastern branch of the area, in Bundelkhand and the Son valley, they rest with little or no unconformity upon thick deposits of very different character. These lower beds were at first noticed under local names in the several areas, but the convenience and fitness of having a common name for deposits so nearly related was soon felt, and the term lower Vindhyan has been used in this sense.

Lower Vindhyans, Karnul area.—Of the original Vindhyans, now specially distinguishable as upper Vindhyans, no certain equivalents have been recognised south of the Son-Narbada valley, but

of the lower Vindhyans many local representatives are known. Of these the one most closely related to older rocks is the Karnul formation, which lies almost altogether within the basin of the Kadapah upper transition series (see page 60), where it is found in two separate areas; the larger one occupies the whole of the Khundair valley and stretches to beyond the Krishna; the other lies in the district known as the Palnád. The formation here might, without difficulty, be regarded as a member of the Kadapah series: its total thickness is only 1,200 feet, which is less than the smallest group of the Kadapahs; its unconformity to the groups below it is but little greater than these exhibit among themselves; and on the east side of the basin it has undergone the full effects of the disturbing forces which have acted upon the underlying rocks.

The Karnul formation has been divided into the following groups[1]:—

Khundair group . .	Shales (Nandiál). Limestones (Koilkuntla).
Páneum group . .	Pinnacled quartzites. Plateau quartzites.
Jamalmadgu group . .	Shales (Auk). Limestones (Narji).
Bánaganpili group . .	Sandstones.

It is principally a limestone formation, with subordinate bands of sandstone and shale. The Bánaganpili sandstone, so called after the town of that name, is usually only from 10 to 20 feet thick, and is sometimes altogether overlapped. There are local signs of its partial denudation below the succeeding limestone, but, on the other hand, some bands of sandstone or quartzite intercalated at the base of this limestone suggest a continuance of the conditions and a close connection of the rocks.

The interest of the Bánaganpili sandstone is, that it is the principal, if not the only, rock of this region in which the diamond is known to be found. Diggings are carried on in many parts of the country on or near the Karnul formation, but mostly in the superficial gravels. At Bánaganpili, however, there have been extensive workings in this bottom sandstone. Shallow pits, not more than 15 feet deep, are sunk in the sandstone, and short galleries driven in the diamond-layer, which must be at the very base of the group or close to the bottom bed. Superficially, the sandstone is hard and compact, and has quite the character of a quartzite; but even at the small depth sunk to, the beds are soft and easily worked.

The Bánaganpili group consists of sandstones, generally coarse, often earthy, occasionally felspathic or ferruginous, and usually of dark shades

[1] Memoirs, G. S. I., Vol. VIII, p. 30.

of red, grey, and brown colours. Pebble-beds are frequent, the pebbles being small and very numerous, composed of quartzite and various coloured cherts, jaspers, and hardened shales, evidently derived from the cherty shales with bands of trappean rock of the Cheyair group of the Kadapah series on which the Bánaganpili beds rest. The diamonds occur in some of the more clayey and pebbly layers. Mr. King records the opinion that they are innate in this rock; but the *gisement* certainly suggests that even in this position they are of detrital origin. It is rather mysterious why the rock-workings should be so crowded as they are over certain spots, whilst large adjoining areas of apparently the very same deposits are left quite untouched. If this irregular distribution of the mines be only due to a delusion of the diamond-seekers, there is still a very large field awaiting exploration.

The Jamalmadgu group takes its name from a large village on the west side of the Khundair valley. It is composed at top of buff, white, and purplish, non-calcareous shales, well seen near the village of Auk (Owk). They have a maximum thickness of 50 feet, and pass down gradually into a finely crystalline or compact limestone, generally blue-grey, sometimes nearly black, and occasionally of pale buff and fawn colours. A very inferior lithographic stone used to be obtained from these beds, but the rock is now much used for building, large quarries having been opened near the railway at the village of Narji, by which name the stone is known. West of Bánaganpili, the Narji limestone is about 400 feet thick, but thins out both to the south and north. In the Raichur Doab, about Karnul, it rests on the metamorphic rocks, where it becomes cherty and brecciated in a peculiar manner, and is there described as a shore-deposit.

Between the open Khundair valley and the western ranges, or Yerramale, there are in the Karnul district some low, flat hills, such as the plateaus of Upalpád and Undútla. These low plateaus are composed of a middle sandstone or quartzite band found locally intercalated in the Karnul limestones and known as the Páneum group, after the town of that name. The greatest thickness of the quartzites is only 100 feet, and the group disappears altogether to the north and south; nor has any sign of it been observed on the eastern edge of the basin. An upper portion formed of firm white sandstone has been distinguished as the 'pinnacled quartzite,' from its mode of weathering; the lower beds, or 'plateau quartzites,' are coarser, more earthy and ferruginous, of various rusty tints.

In a basin of slightly disturbed strata the uppermost group must cover the largest area, and so the Khundair beds occupy the whole valley of

the Khund. There is a thickness of 500 to 600 feet; the upper two-thirds, of purple calcareous shales and earthy limestones, being distinguished as the Nandiál shales, after a large village of that name: they pass insensibly down into purer, compact, and crypto-crystalline, flaggy limestones known as the Koilkuntla band, from a town ten miles south-east of Bánaganpili. The town of Kadapah (Cuddapah) and all the large villages in the centre of the valley are on the Nandiál shales. In this position the rock is soft and crumbling, but to the south and east, on the margin of the mountain region, these uppermost beds of the whole sedimentary basin are quite slaty, being cleaved and contorted proportionally with the underlying formations. In this group also the character of the limestones changes to the north-west, in the proximity of the metamorphics, where the Koilkuntla beds are described as shore-deposits that never extended much beyond their present boundary.

The Palnad area.—The Palnád limestone appears to represent the Karnul formation; and even the sub-divisions have been in a manner specifically recognised in the south-west part of the ground. The limestone is everywhere underlaid by a diamond-bearing sandstone, which has thus been supposed to represent the Bánaganpili rock. In the Palnád country, however, there is great difficulty in distinguishing this rock from a closely associated sandstone clearly belonging to the Kadapahs, but of the Krishna group, at the very top of the Kadapah series and several thousand feet higher stratigraphically than are the beds of the Cheyair group underlying the diamond-sandstone of Bánaganpili. Such at least is the position made out for the bottom sandstone on the south-west of the Palnád towards the expanding rock-basin; on this side, too, some slight unconformity has been pointed out between the Palnád limestone and successive masses of the sandstone, and it has been remarked that the diamond workings here are confined to the rock close under the limestone, so as to suggest the limitation of diamonds to the horizon of the Bánaganpili group. All round the north-east corner of the basin, however, this sandstone, there known as the Jagiapet quartzite, rests directly upon the gneiss.

The leading structural character of the Kadapah basin is maintained in the Palnád: on the west side the strata are comparatively undisturbed, while on the east border they are cleaved, foliated and contorted, and this involves for the Karnul formation a puzzle analogous to that already noticed for the Kadapah rocks (p. 65). According to one interpretation, there would be in the eastern ranges a natural ascending sequence of shales, limestones, and quartzites above what have been described as

the Palnád limestones, and so these upper rocks would be newer members of the Karnul formation; according to another view, this sequence is deceptive, being due to total inversion of the strata, the top quartzite being really a Kadapah rock.

The relation here exhibited shows how arbitrary is the seemingly broad distinction between the upper transition and the Vindhyan series.

The Bhima basin.—On the north-western border of the Kadapah basin, the Karnul deposits are described as overlapping the formations upon which they, for the most part, rest, and as lying upon the gneiss for a short distance up the Krishna valley. Seventy-five miles farther in this north-westerly direction another area is found of rocks having a strong likeness to the Karnul deposits, and resting throughout their entire south-east border, for a distance of more than a hundred miles, immediately upon the gneiss, while along their entire north-western border they are covered by the Deccan trap. The width of the basin thus exposed is exceedingly variable, both boundaries being very irregular in outline. It is greatest, about twenty-five miles, where the Bhima river crosses the outcrop nearly at its middle. From this circumstance the name of the river has been taken for the local designation of the rock-basin.[1]

The Bhima series is mainly a limestone formation, with a total thickness of about 1,000 feet. The following beds have been distinguished in it:—

	Feet.
UPPER.	
(*g.*) Red calcareous shales of Muduwal	30
(*f.*) Flaggy limestone beds of Jewargi	
(*e.*) Buff shales of Gogi	18
(*d.*) Quartzite (sandstone) of Hottapati	200
(c^2.) Blue thick-bedded splintery limestone, brecciated in part	200
(c^1.) Thin-bedded limestone, with chert, of Gogi, &c.	200
(*c.*) Blue and grey splintery limestone, occasionally brecciated, of Shahabad and Talikot	200
LOWER.	
(*b.*) Purple, red, drab, and dark-green shales of Nalwar, with calcareous flags at top	100
(*a.*) Quartzites (sandstones) and conglomerates	60
gneiss.	

It is principally in the south-western part of the area that the bottom sandy beds are developed to any extent. The pebbles of the conglomeratic bands are derived from the adjacent metamorphics, upon a very uneven surface of which the Bhima deposits were laid down, as is shown by

[1] Mr. Foote: Memoirs, G. S. I., Vol. XII.

the very winding outline of the boundary, and by the occurrence of gneissic inliers, some of which are found near the trap of the north-western edge of the area. There is thus no presumption that the sedimentary basin extends far beneath the eruptive rock.

At Bachimali, the extreme easterly point of the southern expansion of the Bhima basin, there is a basement pebble-bed much resembling the diamond-layers of the lower Khrisna valley; it is much broken up by small pits, as if at one time it had been searched for diamonds; but there seems to be no local tradition of any having been found.

The Hottapati sandstone also is quite a local intercalation, so that in some sections the formation is almost exclusively made up of limestone. This is for the most part a very fine-grained rock, with a texture approaching that of lithographic stone. The colours are very various; grey prevails, but drab and pink tints are common. The rock generally occurs in flaggy beds, and is much used for building; the pale cream-coloured variety being preferred by the natives, although the grey stone is the more durable.

The formation has undergone very little disturbance, and the inclination of the strata very rarely exceeds from 2° to 5°. At a few places near the boundary, some crushing and faulting has taken place, as at Gogi, where the lowest beds seen near the gneiss, along an east and west line, are vertical.

There are some patches of a singular limestone-breccia resting on the gneiss within the confines of the Bhima basin, as west and north of the village of Yeddihalli in the Agani valley. The brecciation has clearly been caused *in situ*, and Mr. Foote (*l. c.*, p. 162) conjectures that these patches may be remnants of a former spread of the Kaladgi rocks.

With the exception of a doubtful fragment of silicified wood (or bone) found by Mr. Foote in the basement conglomerate close to the village of Kusukunuhal, just within the Agani valley, no traces of organic remains were obtained from any of the Bhima rocks. Mr. Foote speaks of the limestones as a pelagic formation, and remarks that there is a good deal to suggest that they were once continuous with the like rocks of the Karnul area, and that they have been separated only by denudation.

Mahanadi and Godavari areas.—Between the Karnul and Bhima basins on the south, and the main Vindhyan basin on the north, of which somewhat detailed descriptions have been published, there are numerous areas, some of them very extensive, in the Máhánadi and Godávari river-basins, occupied by rocks belonging either to the lower

Vindhyan or to the upper transition series. These rocks consist of limestones and shales, mostly in low ground, and of quartzite-sandstones, commonly forming ridges and plateaus. They have only received cursory notice in connexion with the adjoining formations, or during rapid preliminary surveys of large areas. Mr. Blanford first noticed them in the country on the Pemganga south-west of Chánda and conjectured their Vindhyan affinities; he considered the sandstone to be the lower member of the series. Coming from the south, Mr. King recognised the quartzites of the Pakhál country north of Kamamet as Kadapahs (they are coloured so on the map accompanying this Manual), and certainly one would *primâ facie* conjecture them to correspond with the bottom sandstones of the Palnád on the Krishna. An observer from the north, familiar with the lower Vindhyans of the Son valley, considered the limestones and shales of the plains of Chhattísgarh to represent that formation. This opinion is now quite general as regards the purple shales and limestones of these several areas, but there is still considerable doubt as to the position of the sandstone or quartzite.

That this doubt should exist implies that the limestones and shales are obscurely connected with the sandstones, or scarcely at all associated. The concomitant opinion that the sandstones are Kadapahs implies that they are apparently the older of the two groups; they are in fact in almost every known section of superposition found to rest upon gneiss, as is nowhere recorded of the limestone and shale group. It has, indeed, been considered by some[1] that the sandstone is the youngest member of the series, apparently for the reason that in contiguous position it occupies the higher ground; this view being reconciled with the fact of the sandstone resting on gneiss, by the supposition of overlap. Elsewhere, however, as along the east border of the Máhánadi basin, the relation has been described as of the sandstone rising from beneath the limestone over an elevated area of gneiss, whether as an original shore-deposit or by subsequent elevation.

It would of course remove the difficulty to suppose that there are two sandstones, but this must not be done without some positive evidence, and Mr. Ball has recently brought some forward from his exploration of the unknown country between the Máhánadi and Godávari.[2] On the upland to the west of the main range of crystalline rocks, the summits of which rise to above 4,000 feet, there is the Nowagarh-Kariál plateau, having an area exceeding 750 square miles, and an elevation of over 3,000 feet, formed of Vindhyan sandstone. Although a plateau, on an

[1] Mr. Hughes: Wardha Valley Coal-Field, Memoirs, G. S. I., Vol. XIII, p. 11.
[2] Records, G. S. I., Vol. X.

upland, it is stratigraphically a basin, the scarp being formed mostly of the top beds resting upon an undercliff of gneiss. In the deeply cut stream-courses, one of which passes right through the plateau, from west to east, a thickness of about 1,500 feet of the sandstone is seen unmistakably resting upon red shales, which greatly resemble those associated with the limestone of the Chhattísgarh and the Pemganga areas. Mr. Ball considers that their identity is probable, and that if so, the Nowagarh sandstone may possibly represent the upper Vindhyans of the great northern basin, for which hitherto no representative has been found south of the Son. These suggestions, however, need confirmation: to show that the Nowagarh sandstone is not the same as that described to rise eastwards from beneath the shales and limestones of Chhattísgarh. It would be passing strange, if this great limestone basin of the upper Máhánadi valley had ever been overlaid by a strong sandstone like that of Nowagarh, that no remnant of this should be left except round the border. The reverse process of denudation is conspicuously the case in the northern Vindhyan basin. It should also be noticed that limestone was not observed with the shales of the Nowagarh basin, whereas it is the most conspicuous rock of the main areas.

The limestones and shales of Chhattísgarh are known to have a great extension, stretching from near Sambalpur for nearly 200 miles westward to the foot of the Mandla plateau. They are believed to occupy the whole of the upper Máhánadi valley, and to stretch across into connection with the like rocks occupying a large area of Bastar, in the upper valley of the Indrawati. The rock-basin would thus have an extent from north to south of about 250 miles, and cover a larger area than the Kadapah basin.

In comparison with this, the ground covered by these rocks in the valley of the Pemganga is insignificant, but there is here the rare occurrence of lower Vindhyan in contact with Gondwána rocks. Along their entire eastern border the limestones and shales of the Pem are overlaid by different groups of the coal-bearing series, or faulted against them. The Pem Vindhyans are covered on the west by the Deccan trap, as are the corresponding deposits on the Bhima.

It was mentioned that the lower Vindhyans of the Karnul and Bhima basins may have been originally continuous, denudation being apparently sufficient to account for their separation. A similar conjecture cannot be so plausibly extended to the limestones and shales of the several basins in the Máhánadi-Godávari area: if the sandstones resting on the gneiss around the borders of those basins belong to an upper group of the series, their overlapping the lower beds would, of course,

debar the supposition. Pending the settlement of this question, we may notice that the disturbance known to have affected these rocks would be enough to account for portions of a once continuous deposit being now completely isolated: the folding and inversion of the Karnul beds along the west flank of the Nallamale (Nullahmullay) in the Kundair valley and the Palnád has been already described; the strata on the east side of the Noagarh plateau were observed by Mr. Ball to be similarly faulted and folded; and a like condition obtains along the north-east border of the Chhattísgarh basin, from Sambalpur to the north-west.

The diamond-washings of the Máhánadi a little above Sambalpur are exclusively from alluvial diggings; but the fact that they occur just outside and below the great lower Vindhyan basin has suggested the conjecture that the gems are derived from those rocks, on the ground that these are the equivalents of the diamond-bearing beds of Southern India. If the conjecture were confirmed, it might be taken as a point in evidence of the equivalence of the formations.

Son area.—There is a much wider and more distinct barrier between the great northern Vindhyan basin and the Chhattísgarh, or upper Máhánadi area, than between the latter and any of the affiliated rocks to the south. The ridge of gneiss which to the west forms the well-raised base of the basaltic plateau throughout the districts of Mandla, Seoni, Chindwára and Betúl, and to the north-east forms the highlands of Chutia Nágpur, is interrupted at this point. It is here that the Gondwána deposits stretch across from the Son to the Hasdu and thence down the Máhánadi valley. The watershed between the Son and the Máhánadi drainage is pretty high, and is occupied by Tálchír rocks, probably of no great thickness: we know, too, that the Vindhyan boundary on both sides runs free of the Gondwána rocks, so it is almost certain that the gneiss must form a rock-barrier from east to west; though of course it is open to question when this may have been produced; it may well be of post-Gondwána age. The junction of the metamorphics with the Vindhyan rocks of the southern area is reported to be abrupt and troubled; but on the north, in the Son valley, observations rather suggest an original limit of the Vindhyans in about the present position; we find the bottom beds constantly at the boundary, and certain coarse deposits on this horizon thicken to the south, presumably to the rise of the original basin.[1]

The map prepared for this Manual is on so small a scale, that one colour has to serve for the whole Vindhyan system; but it is only in the northern basin, where both upper and lower series occur together, that

[1] A description of the Vindhyan rocks of the great northern basin by Mr. F. R. Mallet is published in the Memoirs, G. S. I., Vol. VII.

this might mislead, and it is easy to indicate the narrow limits to which the lower formation is confined. From Sasseram, at the extreme east end of the area, the lower Vindhyans are continuous at the base of the Kaimur scarp for 240 miles; and they disappear at the Son-Narbada watershed, where the upper Vindhyans sweep across into contact with the submetamorphic rocks. The greatest width of the lower Vindhyans across their outcrop in this their typical area is 16 miles, and it is exposed just where the Son enters its main valley from the south. At some points on the lower reaches of the river their outcrop is less than two miles wide. Some small inliers appear through the alluvium in Behar, at a short distance east and north of the termination of the Vindhyan plateau, most, if not all, of them of lower Vindhyan rocks, which also crop out from beneath the upper Vindhyans in some of the valleys on the north side of the plateau west of Sasseram. In this direction, however, the lower Vindhyans soon disappear; and at the lowest level, where the Ganges washes the base of the plateau, at Chunár, only upper Vindhyans are exposed. The concealment of the lower groups is probably only due to depression in the main axis of the basin, for the very same rocks appear again beneath the Kaimur sandstone as it rises towards the gneissic mass of Bundelkhand.

A list of the lower Vindhyans of the Son valley, in approximate order of succession, is as follows (in descending order):—

11. Limestone.
10. Shales.
9. Limestone.
8. Shales and sandstone.
7. Limestone.
6. Shaly sandstone.
5. Porcellanic shales.
4. Trappoid beds.
3. Porcellanic shales.
2. Limestone.
1. Conglomeratic and calcareous sandstone.

These lithological characters by no means indicate well defined or constant zones in the series; they are all very variable, and pass into each other both vertically and horizontally, by interstratification and admixture of ingredients, and by reciprocal expansion and contraction. The sandstone of No. 8 is steady for 100 miles in the west, forming the conspicuous Kainjua range of hills, and is almost absent to the east, where No. 7 is much more prominent. In the reach between Agori and Bardhi, where the whole formation is most constricted, Nos. 3, 4 and 5 are scarcely represented, and 6, 7; and the sandstone of No. 8 entirely absent. The uppermost beds, Nos. 9, 10, and 11, which collectively might be called the Rotás group, are the most constant of any; and the bottom rocks, Nos. 1 and 2, the most inconstant, which may be explained by their being most affected by the irregularities of the surface on which they were

deposited. All these conditions indicate the unity of the series as a whole. It may have altogether a thickness of 2,000 feet. The petrological resemblance of the lower Vindhyans of the Son valley to those of the southern basins is much less than these latter bear one to another.

The unconformity of the Son lower Vindhyan series upon the transition rocks is total. The bottom conglomeratic beds are often made up of the subangular debris of the Bijáwar jaspideous quartzites, and rest flatly upon the vertically upturned strata of the same. The boundary between the two formations is often straight for considerable lengths, and is otherwise seemingly abrupt, as if faulted; but the local bottom-rock always occurs at the contact; and the numerous and distant Vindhyan outliers, at a slightly greater elevation on the schists to the south, show that the original floor of deposition has not undergone much irregular displacement. Even this rise to the south would seem to be to some extent an original feature; for in these outliers the conglomeratic sandstone, which is the usual bottom-rock, is found in much greater force than elsewhere; it is often very thin, and locally altogether absent at the main boundary, No. 2 or even No. 3 taking its place as bottom-rock: facts which have suggested an original shore of the deposits in this position.

The peculiar pseudo-trappean rocks already noticed in the Gwalior and Kadapah formations are more extensively displayed in the Son area, constituting Nos. 3, 4, and 5 of the list, which attain an aggregate thickness of about 300 feet. The middle beds are the most trap-like; they consist of a rock principally made up of a finely saccharine silicio-felspathic paste, in which innate globular felspar and quartz are unevenly scattered. Where the felspar occurs in nests, it is commonly surrounded by a dark-green, amorphous hornblendic-looking mineral. An analysis (by Mr. Tween) of two samples of these rocks gave the following result:—

	Porcellanic rock.	Trappoid rock.
Soluble in acid	5·5	4·8
Insoluble	94·5	95·2
Silica	86·81	79·35
Alumina	6·25	12·23
Iron sesquioxide (present also as protoxide with a trace of sulphide)	8·10	2·50
Lime	0·12	0·14
Magnesia	trace	trace
Potash	4·10	4·50
Soda	1·00	3·10
	101·38	101·82

The pseudo-trap is particularly well developed in the east about Kon Khás and in the inliers in the alluvium at the mouth of the Son valley. In some of these it rests upon the gneiss, and in such cases it is very difficult to draw a line between the Vindhyans and the metamorphic rocks. The porcellanic beds, as elsewhere, are most regularly and distinctly bedded, and on weathered surfaces they often exhibit minutely fine and continuous lamination. The circumstance that these peculiar beds are most developed east of the Rehr and west of the Gopat, where granitic rocks are abundant in the adjoining areas, suggests the detrital origin of the shales from their crystalline neighbours. The rocks Nos. 1 to 5 of the list may be considered as a lower division of the series in the Son valley.

The porcellanic beds pass gradually up into the shales of No. 6, which, with Nos. 7 and 8, form a middle set of the series on the Son. The shales of No. 6 are easily abraded, and therefore are much concealed. The limestone No. 7 is most developed in the east, where, owing to undulations of the strata, it forms several ridges between the Son and the Kaimur scarp. In the west it is found along the south base of the Kainjua range of hills, formed of the sandstone of No. 8; and this range for a space almost rivals the Kaimur scarp. To the west again the sandstone splits up, and the range comes to an end close to Bijirágugarh.

Some concretionary calcareous shales of No. 8 form a gradual passage into the limestone No. 9, which with 10 and 11 forms the upper division of the series of the Son, more united even than the beds of the middle and lower divisions, for locally the whole thickness is formed of limestone, as at Rotásgarh, the ancient hill-fort at the eastern extremity of the Vindhyan plateau. The limestone is generally distinctly and thinly bedded, and fine in texture, either microcrystalline or compact. It is exceedingly various in composition, sometimes pure, sometimes dolomitic, silicious or earthy. Through the gradual predominance of this latter ingredient it passes both horizontally and vertically into fine flaky silicious shales, No. 10 of the group, which are not confined to any strict horizon, though they occur very generally near or at the top. The thickness of the Rotás group is variously estimated at 700 to 900 feet. It is the most constant member of the lower Vindhyan series in this basin; it appears along the base and in front of the Kaimur range along the whole Son valley from Rotásgarh to where it passes under the upper Vindhyans near Bilheri, a little way to the west of the railway line, and close upon the Son-Narbada watershed. It would thus be more in natural order to speak of the lower Vindhyans becoming uncovered here and gradually more exposed down the valley; the top of

the limestone at Rotás has about the same elevation as the first outcrop near Bilheri at the head of the long valley.

West of the watershed, there is only one small re-appearance of the lower Vindhyans. They disappear at Bilheri under an anticlinal arch of the upper series, which here stretch across to come in contact with the transition rocks along a faulted boundary. In a valley north-east of Kutungi, about 30 miles west-south-west of Bilheri, the top of the anticlinal has been denuded and the lower Vindhyans exposed. For a long way to the west of this no crucial sections are exposed; but where the Vindhyans are next found in original (normal) contact with older rocks in the Dhár forest the lower series is absent. It is also wanting all along the north-west boundary in the Arvali region; and it is equally deficient along the whole western edge of the Bundelkhand gneiss.

Any further description of the stratigraphy of the lower Vindhyans in this basin must be taken up with that of the upper series, which conformably overlies them.

The Bundelkhand area.—It may be considered certain that the Semri rocks under the Kaimur scarp in south-eastern Bundelkhand are the same as the lower Vindhyans of the Son valley, but their appearance on the north is much more irregular in every way—a circumstance which is easily accounted for. From Chebu, close to the Jumna, they are seen at intervals below the Vindhyan scarp for 160 miles, to beyond the Dhasán. The principal exposures are—for 20 miles east of the Dhasán, and for 12 west of the Kén (Cane). East of the latter river the beds are totally concealed for long distances where the upper Vindhyans pass over them on to the gneiss, and the lower formation is only visible in the gorges of the principal streams. About Kirwi, again, where the main scarp begins to trend eastwards, oblique to the general strike of the basin, the lower Vindhyans are freely exposed; but at Bhíta, where the Jumna first touches the rocks of the plateau, a few miles above Allahabad, the upper Vindhyans are at the water-level, the position being more to the dip of the basin.

The rock-groups more or less distinguishable in the lower Vindhyan series of Bundelkhand are as follows (in descending order)[1]:—

5. Limestone (Tirhowan).	3. Sandstones (Dalchipur).
4. Shales (Palkoa).	2. Shales and limestone (Semri).

1. Sandstone (Semri).

Of these, Nos. 4 and 5 very circumstantially represent the Rotás group of the Son—the thin, sharply bedded, fine-grained limestone, of very variable composition both in chemical and mechanical ingredients, and the flaky silicious shales between which, more capriciously than in

[1] Memoirs, G. S. I., Vol. II.

the Son area, the most complete transitions occur vertically and horizontally. When the Bundelkhand ground was first described, the equivalence of these different rocks was not detected, and consequently it was supposed that the shales had suffered denudation before the deposition of the limestone, and the limestone again before the deposition of the Kaimur sandstone (upper Vindhyan), which is found resting directly on both. In one form or the other, as shale or limestone, this group is found from end to end of the outcrop, being, like the Rotás group, the only constant member of the series.

There is one character connected with this limestone in Bundelkhand that does not occur in the Son region: it is almost constantly overlaid by a silicious breccia, not a detrital rock nor a contortion-breccia, but apparently composed of thin layers of agate, chert and jasper, shattered in place either by concussion or desiccation, and re-cemented by sintery or hyaline silica, free from sand or other detrital matter. This breccia is rather connected with the limestone than with the overlying Kaimur sandstone, which often has at its base a breccia-conglomerate very different, however, in character from the Tirhowan breccia, which is adherent to the limestone, and also fills cracks in its upper surface. This bed is sometimes 40 feet thick, as on Panwári hill, south-east of Tirhowan.

Some black concretionary shales in No. 2 may be supposed to represent the exactly similar beds in No. 8 of the series in the Son valley. In both localities explorations for coal have been made in these beds by sanguine adventurers. No further similarities can be traced between the two series: the lower groups in Bundelkhand are even more inconstant than those of the Son.

The greater irregularity of the groups at the outcrop in Bundelkhand is manifestly due to this being the original edge of the deposits. In the Son the neighbourhood of an original boundary not far to the south is suggested, but in Bundelkhand the whole feature is fully exposed. In the gorge where the Semri undercuts the section from north to south, the Semri sandstone does not follow up the rise of the Bijáwar rocks in parallel bedding, but is banked against it in lenticular masses. At the head of the lateral valley to the west, under Chopra, the Semri shales are seen to stretch up against this bank of sandstone with a gradually diminishing thickness, and are in turn cut off by an overlapping sandstone, representing the Dalchipur rock of the Dhasán area, which is itself covered and overlapped by the Kaimur (upper Vindhyan) sandstone, the Tirhowan limestone being altogether cut out, but it occurs in force at the base of the scarp along the principal valley a short distance to the south.

Each of the groups in turn, except perhaps No. 2, is found at or very near to the base of the series. In the west, at the Dhasán and east

of it, the Dalchipur band is the dominant or even the only member present. Near the east bank of the river there is a remnant, about 10 feet thick, of the Semri sandstone, but on the west, under Kurat, the thick pebbly Dalchipur rock lies close upon the Bijáwar greenstone; and to the south nothing is seen between the Dalchipur sandstone and the Kaimur conglomerate. However similar these two conglomerates may be in general characters, they have one striking distinction—the pebbles in the Dalchipur rock are all of white quartz, while those of the upper Vindhyan rocks are almost entirely of red jasper, just like the Gwalior stone. This contrast in itself suggests a great change in the conditions of formation; it may even be a hint that the Gwaliors and lower Vindhyans are nearer to each other in age than our classification would indicate.

In the middle area, at and west of the Kén, the Semri sandstone and the overlying shale and limestone band are well developed. The latter is also fairly seen in the gorges of the Ranj and the Boghin, east of Panna; but in the eastern area, about Kirwi, the Tirhowan (Rotás) limestone, very free from its familiar shales, is with one exception the only member of the series. The exception consists in a very peculiar bottom-rock covering the granitoid gneiss. Where found under the limestone this rock might readily be referred to the Tirhowan group, for it often has layers of dense, fine limestone just like that rock, and it is otherwise cherty, as is often the case with the limestone; but it is largely a detrital rock composed of quartz-sand, felspar-grains, and (characteristically) glauconite. Cherty segregation in many forms—spongy, pisolitic, amygdaloidal or disseminated—gives its most peculiar aspect to the bed. This rock is traceable in the hills south-west of Kirwi, the most north-westerly of which, about Akbarpur, are altogether of metamorphic rock and have a pointed or rounded outline; the next have only a thin cap of Kaimur sandstone; but the sedimentary beds thicken steadily to the south-east, and at the sacred hill of Chattarkot the gneiss appears only at the base on the north-west side. At the high elevation of the junction there is only a remnant of the cherty contact-rock coating the gneiss under the Kaimur sandstone, and in Chattarkot hill the contact-rock occurs under the limestone, holding its position as a true bottom-rock. At a few places in the eastern area the flaggy sandstones of this band are well marked, as in the gullies to the south-east of Chattarkot hill; and they become more developed to the west, as north of Panna on Bisrámganj Ghát, where they are 50 feet thick. In this way they are traceable into relation with the Semri sandstone, in which also glauconite-grains are of common occurrence.

This peculiar contact-rock of the east has been more specially noticed because of a conjecture that it may possibly be an original *nidus* of the

diamond. A common form of it is a semi-vitreous sandstone, or pseudo-quartzite, of a greenish tinge, the result of the local solidification of the sandstone by diffused silica. Large pebbles of this rock are very abundant in the conglomeratic diamond-bed of the Rewah shales at the Panna mines, and it is said they are broken up in the search for diamonds. The diamond-bearing beds of the upper Vindhyans are now at a much higher level than any existing outcrop of the Semri beds; but it is very probable that this peculiar rock once extended over the then elevated surface of the gneissic area. It is, of course, only in view of the remarkable steadiness of the actual horizon of the Kaimur conglomerate and its overlap on to the gneiss, as described in Bundelkhand, that any suggestion need be offered as to how debris of *infra*-Kaimur beds can have found their way into *supra*-Kaimur deposits.

Upper Vindhyans.—The upper Vindhyan formation[1] ranks third in superficial extent within the rock-area of the peninsula, occupying in a single basin a larger surface than the combined areas of any other formation except the gneiss and the Deccan trap. The form of the basin is peculiar: there is a great area, 250 miles long, between Chittorgarh on the west and Saugor on the east, and 225 miles broad from Indargarh on the north to Barwai (or Mortaka) on the south, all presumably occupied by upper Vindhyans, although a very large part of it is covered by the trap of the Malwa plateau. From Saugor a long arm, with a maximum width of 50 miles, stretches eastwards for 340 miles to Sasseram in Behar. Another broader tract extends northwards from Saugor, and passes under the Gangetic alluvium between Agra and Gwalior. The gneissic mass of Bundelkhand lies between these prolongations. The exposed surface of the upper Vindhyan deposits is about 40,000 square miles; and with the area beneath the trap the basin would occupy about 65,000. The classification of the strata composing the upper Vindhyans is as follows:—

Bhâneer (*Bundair*)	Upper	13. Sandstone.
	Lower	12. Shales (Sirbu).
		11. Sandstone.
		10. Limestone.
		9. Shales (Ganurgarh).
Rewah	Upper	8. Sandstone.
	Lower	7. Shales (Jhiri).
		6. Sandstone.
		5. Shales (Panna).
Kaimur (*Kymore*)	Upper	4. Sandstone.
		3. Conglomerate.
	Lower	2. Shales (Bijigarh).
		1. Sandstone.

[1] Memoirs, G. S. I., Vol. VII.

The upper division of the Vindhyan system is in the main a sandstone formation, with distinct bands of shales, mostly coarse and flaggy. The only limestone is a subordinate band occurring pretty constantly throughout the area in the Bhánrer group, but the lower Rewah shales (Panna) are locally calcareous. Both the chief and minor sub-divisions are wonderfully persistent over the whole of the great basin, all being found in both the eastern and northern areas into which the main area is divided by the Deccan trap. The lower Bhánrer and lower Rewah sandstones are very attenuated in certain directions, but there is an equivalent increase in the thickness of the enclosing shales. In certain positions also the great bands of shales thin out altogether, and the main sandstones coalesce. These reciprocal variations in the distribution of the coarser and finer deposits have distinct relation to position with reference to the border of the area, the shales being in force towards the middle of the basin, and being replaced by sandstones near the margin, showing that this border is approximately an original limit, and that the actual basin corresponds pretty closely with the basin of deposition. There are local exceptions to this condition, and it is in the direction in which these exceptions occur, *viz.*, on the Arvali side, that the only recognisable distant outliers of the upper Vindhyans have been observed.

A formation so constituted, and for the most part but little affected by disturbance, can result in but one form of surface; accordingly the upper Vindhyan area presents a three-fold plateau, each step formed of one of the main groups, with minor plateaus, terraces or ledges corresponding to the various sub-divisions. The thick sandstones form vertical scarps over a talus of the underlying shales. There is, moreover, a basin-shaped lie of the beds, apparently to a great extent original, whereby the surfaces are rendered more or less concave, and the edges of the successive scarps of sandstone scarcely higher than the outer one composed of the Kaimur rock. From this arrangement it follows that the upper group occupies by far the larger part of the area: even the middle step of the plateau, the edge of which is determined by the Rewah sandstone, is chiefly occupied by the lower Bhánrer shales.

The Son-Narbada boundary.—The lower Kaimur beds are the least exposed of any, and are only known in the eastern arm of the basin, and very locally in Bundelkhand. They are best seen in the gorge of the Ghágar north-east of Agori, under Bijigarh fort, where the shales are 150 feet thick, and the lower sandstone 200 feet. These shales are quite black, and were explored for coal in 1837; but no trace of any such mineral has ever been found in them, or in any part of the Vindhyan series. For some distance to east and west the outcrop of these shales

produces a double scarp on the face of the Kaimur range; but at the extreme eastern end at Rotás the shales are scarcely, if at all, represented, the sandstones forming an unbroken mass.

At this end of the basin the whole Kaimur group is estimated as 1,300 feet thick. In going westward up the Son valley it gradually decreases, disappearing altogether at the watershed, where the Rewah sandstone rests upon the lower Vindhyans, the whole of the lower Rewahs having also vanished. This actual diminution of the Kaimurs and the lower Rewahs westward, along the southern outcrop of the basin, is in reality only due to the thinning out of the deposits southwards, presumably to the rise of the basin, and to their overlap by later beds of the series; for, in passing westwards from Rotás along the northern outcrop, the Kaimur beds continue in force throughout the whole border up to Gwalior; and at the gorge of the Kén, which is about opposite to the head of the Son valley, the group is manifestly thickening to the south, some fine greenish shales appearing at the deepest points of the sections under the Kaimur conglomerate. The group is also well represented along the western border in Rájputána.

At the Son-Narbada watershed, where the Kaimurs are overlapped, the other groups of the formation have been estimated (at Kuttangi) as follows:—

Upper Bhánrers	650
Lower „	1,450
Upper Rewahs	1,000
	3,100

The great thickness of upper Rewah sandstone here suggests that the disappearance of the Rewah shales is not purely due to overlap, but partly to replacement. This plan of distribution—the tendency to a greater development of sandstone and a corresponding diminution in the thickness of the intercalated shales towards the actual limits of the formation—becomes more and more developed to the south-west: north of the Narbada near Hoshangabad the series consists of—

Upper Bhánrers	3,000
Lower „	500
Upper Rewahs	6,000
	9,500

And in the Dhár forest still further to the westward the whole formation consists of an enormous accumulation of sandstone, estimated at 10,000 feet, without distinguishable horizons. Mr. Mallet considers that this great sandstone formation probably represents all the groups

elsewhere so persistently separated. The fact that the greatest known accumulation of the upper Vindhyans occurs at the south-western extremity of the area seems to be opposed to the conjecture already made that the whole southern boundary is near the original limit of deposition; but, on the other hand, the absence of the finer deposits at this south-eastern corner of the basin suggests that the sandstones of this part of the basin were formed near the margin of the deposition area. The whole country to the south-west is covered by trap.

Boundary in Bundelkhand.—The border of the Vindhyans in Bundelkhand is more distinctly seen to be related to primitive features of the ground than can be proved in the case of the southern boundary. The bottom bed everywhere, except up the gorges, is the Kaimur conglomerate, forming a scarp over an undercliff of gneiss or of the intervening formations (lower Vindhyan or transition) already described. Where the river gorges afford sections at right angles to the boundary, the conglomerate is seen to thin out, disperse and vanish, other beds of the same group appearing below its horizon. On the Kén, fine shales of decided upper Vindhyan type are found in this position; so that the Kaimur conglomerate, though generally the bottom contact-rock of the upper Vindhyans in Bundelkhand, is not at the very base of the formation.

It is not in the Kaimur group only that evidence of thinning out against the gneiss of Bundelkhand is found. Towards the position where the upper Vindhyans have least suffered from erosion, at the head of the great bay of lower Bundelkhand, the outer (Kaimur) step of the plateau, in both the eastern and northern areas of the basin, gradually narrows, and the Rewah scarp approaches the glacis of the Kaimur scarp. The whole Rewah group does not, however, rise in this direction, as would happen if the basin were one of depression: the Rewah shales die out and the Rewah sandstone creeps up over the lower group, and for many miles forms an inconspicuous feature close behind the Kaimur scarp.

Boundary on the Ganges.—For the 120 miles between Allahabad and Sasseram (or more exactly between Chebu and Chainpur) the scarp of the Kaimur sandstone passes very obliquely across the axis of the eastern arm of the upper Vindhyan basin, connecting the boundary in Bundelkhand with that in the Son valley. For a great part of the distance the Ganges runs close to the plateau, and has, probably, repeatedly struck the base of the scarp at different points, as it now does at Chunár. Altogether, the position is one of special exposure, and no doubt a considerable area of the Vindhyans has been removed; no

underlying rock is exposed, the Kaimur sandstone being everywhere at the level of the river or of the alluvium. Still it does not seem probable that these rocks ever extended far in this direction; for the gentle inward slope of the beds which elsewhere has been found connected with other shoreward symptoms holds good for this part of the boundary also.

Arvali boundary.—Of a great portion of the north-western boundary in Rájputána, we know little more than the position. On the south-west, the Rájputána border seems generally to resemble that in the Son valley or Bundelkhand, and to show a well-marked three-fold division of the series, with a bottom sandstone resting indiscriminately on a variety of gneissic and transition rocks; but the ground has not been sufficiently examined to render it clear whether there are any signs of an original thinning out of the deposits such as has been described elsewhere. The features of this boundary to the north-east are against such a supposition, or at least do not suggest it; for long distances, as at Kerauli, the upper Bhánrer beds are brought into juxtaposition with the Arvali rocks by a great fault, outliers of the Rewah and Kaimur groups resting upon the transition (Arvali) rocks close by on the north-west side of the fault. It is plain that here the upper Vindhyans may once have extended indefinitely to the west. The same may be said of the northern prolongation of this arm of the basin; the whole series, seventy miles wide between Kerauli and Gwalior, strikes steadily to the north-east and so sinks gradually under the alluvial plains of the Jumna. A general section in this part of the basin, taken in a north-west direction through Sipri, gives the following dimensions for the several groups:—

	Feet.
Upper Bhánrers	2,000
Lower „	1,500
Upper Rewahs	300
Lower „	450
Upper Kaimur	250
	4,500

It should be recollected that the lower groups on this section are measured near the edge of the basin. They are probably much thicker, where covered by the Bhánrers in the centre of this area.

Petrology.—The general composition of the upper Vindhyan rocks is as uniform as their general arrangement. Although chiefly made up of sandstones, which are the coarser type of detrital deposits, the fineness of the rock throughout the formation is remarkable. With the exception of the Kaimur conglomerate, which is constantly present as a bottom-bed all round the boundary in Bundelkhand, pebble beds are of rare occurrence.

The Kaimur conglomerate is everywhere conspicuous through the prominence in it of bright red jasper pebbles, presumably derived from the jasper bands so abundant in the Gwalior formation. Where the Vindhyans rest upon the Gwalior beds, the rock is rather a breccia than a conglomerate, the included fragments being quite angular. The amount of this debris throughout such a length of outcrop, to such a distance from the nearest known area of Gwalior deposits, suggests the extensive removal of these peculiar rocks from the position now occupied by the gneiss.

There are general characteristics peculiar to each of the great sandstones. The Kaimur rock is fine-grained, greyish, yellowish or reddish-white, sometimes speckled brown; false-bedding is frequent; massive beds are abundant, but, on the whole, the bedding is of moderate thickness, sometimes flaggy and shaly. The Rewah sandstone is somewhat coarser, and generally presents a mixture of massive strata and false-bedded flags. The Bhánrer sandstone is softer than that of the lower bands, very fine grained and generally distinguishable as of deep red with white specks, or of pale tints with or without red streaks. The beds are generally thinner, and not more than 6 to 18 inches in thickness; but very massive beds also occur, as is exemplified by the great monoliths cut from the quarries at Rupbas near Barhatpur (Bhurtpore). Ripple-marking is common throughout the greater part of the Vindhyans, and occurs in great profusion and variety in the upper Bhánrers.

The different shale-bands of the upper Vindhyans do not present any constant distinctive characters. Thin, sharply-bedded, flaggy, silicious or sandy, sometimes micaceous shales, of greenish and rusty tints, form the prevailing type throughout. Purely argillaceous shales are rare.

The Bhánrer limestone is perhaps the most variable rock of the series. Sometimes there is a considerable thickness, as much as 260 feet, of firm stone; elsewhere there is very much less, the carbonate of lime being apparently disseminated amongst the calcareous shales associated with the limestone and partly taking its place. The limestone is generally earthy and compact, of grey, yellow or reddish tints, sometimes purer and either compact or crystalline. It was in this rock at Nagode that fossils were thought to have been found long ago by Captain Franklin; they were supposed to be *Gryphæa*, and the rock was on this account assigned to the lias. It is not known what became of the specimens, and repeated search at the same locality has failed to verify the discovery. It is highly probable the objects discovered were not organic at all, and quite certain that the specific determination of them was fanciful.

The mutual relation of these sandstones, shales, and limestones is most intimate throughout the upper Vindhyan series. The passage upward, from shale into limestone, or into the great bands of sandstone, is always more or less gradual, by interstratification; while the change into shale at the top of the great sandstone beds is as generally abrupt.

Relation to the lower Vindhyans.—The relation of the upper Vindhyans to all contiguous formations is most unequivocal unconformity, except with the lower Vindhyans. That there is some slight unconformity here too, may be inferred. Overlap-unconformity has been shown to be extensive; but more than this would be presumable if only from the sudden highly contrasting and widespread change from the peculiarly fine deposits of the Rotás group to the Kaimur sandstone; and there is, in fact, evidence for some denudation-unconformity in the recognisable lower Vindhyan debris very sparingly found in the Kaimur deposits. Two deceptive features have, however, given grounds for exaggerating the evidence for a break between the upper and lower Vindhyans: before the entire equivalence of the upper shale and limestone of the Rotás group had been established, it had to be assumed that one or the other had been very extensively denuded before the deposition of the Kaimur beds, and this assumption involved much irregular superposition, although none could be detected in actual sections. The other deception is more important, because it involves the introduction of the higher degree of disturbance-unconformity—the greater or less contortion of the lower Vindhyans before the Kaimur period. This view rested upon the fact that the lower Vindhyans are often found sharply twisted in close proximity to the perfectly undisturbed Kaimurs in the Son valley. The upper Vindhyans themselves have, no doubt, undergone considerable flexure in this zone, as may be seen where they stretch across the main outcrop of the lower Vindhyans of the Son area, on the west at Bilheri and on the east at the Ghágar. But these broad undulations were not at first thought sufficient to include the frequently sharp flexures seen in the lower rock. This opinion had, however, to give way to the fact of invariable complete parallelism of the layers of the two formations whenever a contact could be observed, even in proximity to those contortions. It is important to dwell upon this observation, because some unconformities of this class, reported and insisted on elsewhere, rest upon no other evidence than that found to be fallacious in this case. It may even be suggested that such appearances might possibly be produced independently of any general disturbance of associated thick and thin, or hard or soft, deposits, merely by pressure from an adjoining elevated mass upon yielding underlying beds, as occurs in the familiar case of the 'creep' in coal mines.

Disturbance of the upper Vindhyans.—From the remarks in the preceding paragraph, it appears that the upper and lower Vindhyans have been affected by the same disturbing causes; and it has been said that any violent effects of disturbance are restricted to the south-south-east and the north-west margins of the basin. Two local exceptions to this rule may be noticed. In the Panwári ridge south of Tirhowan, the limestone (Rotás) is capped quite horizontally by Kaimur sandstone. The hill is more or less detached from the main plateau, and in the broken ground intervening, as well seen on the Paisuni and the upper valley of the Ohun, the sandstone is found dislocated and dipping in the most irregular fashion, quite inexplicable by any ordinary mode of disturbance. The displacement is probably due to the underground solution and removal of the Rotás limestone, and the consequent subsidence of the sandstone.

The other special instance of disturbance is not local in the same sense as the last, as it is probably only a symptom of much more that is concealed. It has been said that over the wide expanse of Vindhyan rocks between Gwalior and Nimach, the Bhánrer and Rewah beds lie quite flatly: and it has been presumed that to a considerable extent they stretch in this manner under the trap of Malwa. Close to Jhálra Patan, however, at the northern edge of the basaltic plateau, a sharp axis of disturbance passes from the south-east, beneath the trap, to the north-west, throwing up the Vindhyan strata in an anticlinal flexure, with dips of 70° on each side. Along this steep outcrop the sandstone weathers into long narrow ridges. This feature gradually dies out to the north-west. It is a hint that the disturbance which so violently affects the Vindhyans of the Dhár forest, extends far to the north under the basalt of Malwa.

The disturbance of the strata along the south-south-east border of the Vindhyan basin, to as far west as Hoshangabad, is plainly a recurrence, on the same lines, of the compression which had produced the contortion and cleavage in the adjoining transition and gneissic rocks. It seems to have taken different forms in different parts of the ground. Along the whole Son valley, there is little or no faulting in the zone of disturbance; but at the Son-Narbada watershed one or more faults occur at and close to the boundary, the east-north-east strike being remarkably steady throughout. Down the Narbada valley towards Hoshangabad, the dips in the Vindhyans become unsteady. At Hoshangabad, and again in the Dhár forest, there is a decided predominance of a north-westerly south-easterly strike; and as the east-north-east strike remains constant here in the contiguous transition and metamorphic rocks, it may be

inferred that the former strike is the later of the two; it is that to which the features of the Vindhyans south of Nimach and at Jhálra Patan conform.

The very marked disturbance affecting the north-west boundary of the Vindhyan basin, at least in its northern portion, conforms to the north-east—south-west strike of the Arvali rocks. For a great distance the main boundary is a fault, bringing the Bhánrer group into contact with the Arvali schists; but immediately beyond this fault there are large outliers of Kaimur and Rewah strata, more or less contorted. There is nothing to suggest an original limitation of the deposits in this position.

Diamonds.—In the main Vindhyan basin, diamonds are only known to occur in the upper Vindhyans. Here, as everywhere, the great majority of the diggings are alluvial; but the principal workings, upon which most labour is spent, are in a bed at the very base of the Rewah shales. Notwithstanding the immense range of this group, it is only known to be productive within a small area of the Panna state, on the borders of the Bundelkhand gneiss; and the surface-diggings are confined to the same neighbourhood. Here again, as already noticed of the Bánaganpili mines in Southern India (p. 70), the diamond-layer is conglomeratic; and the inference would seem to be that the diamond occurs as a pebble with the others. The observation recorded (p. 84), that a particular kind of these pebbles at the Panna mines is broken up and searched for diamonds, and that these particular pebbles are derived from a peculiar bottom-bed of the lower Vindhyan series, would of course point to this latter rock as the original nidus of the gem, and thus refer its source to the same horizon as in other parts of India. But the observation in question needs confirmation.

The search for diamonds in Panna is not, however, confined to positions in which the gems could be derived from any existing outcrop of the Rewah shales. There are numerous pits (all apparently[1] surface diggings) in the gorges and on the slope of the upper Rewah sandstone south of Panna, and at a much higher elevation than any present outcrop of the bottom shales or of the lower Vindhyans.

Upper Vindhyan Outliers.—The truncated condition of the Vindhyan strata on their north-western border does not, of course, preclude the possibility of their having come to an end within a short distance on that side also; and the general impression that the whole series consists of deposits formed in land-locked basins has tended to encourage the idea that

[1] The digging is only in active operation during the hot weather, and unless visited at this season, reliable observations cannot be made.

the Arvali area was an area of denudation during the Vindhyan period. There was consequently little expectation of finding representatives of the Vindhyans in that direction. Quite recently, however, in 1876, at Jodhpur, and by Mr. Hacket in 1877, at Sojat, rocks have been observed which there can be very little doubt are upper Vindhyan. The former are described as follows[1] :—

"The sandstones which cover a considerable tract of country in the neighbourhood of Jodhpur, are usually coarse in texture and almost always dull red in colour, though occasionally white or brown. As a rule, they are purely quartzose, but they sometimes contain felspar, and in places they are highly micaceous, the mica being arranged in layers, so as to produce a shaly structure. Small pebbles occasionally occur, and are chiefly composed of quartz, but the rock is not usually conglomeratic: it is, however, often obliquely laminated, and the surfaces of slabs are frequently ripple-marked. The beds are quite unaltered and often nearly horizontal, rolling about at low angles.

"Except for their being rather softer, there is little, if anything, to distinguish these sandstones from some of those belonging to the Vindhyan series. No rocks of this series have hitherto been detected west of the Arvali hills, the great Vindhyan area commencing several miles to the eastward of that range.

"The Jodhpur sandstones were not noticed south-west of Jodhpur. They are found for some distance west of the town and for many miles to the northward, their extent in this direction being quite unknown. They are found stretching from Jodhpur to Pokran, a distance of 90 miles, but much of the intervening country is so completely concealed by sand, that it is impossible to say whether any breaks occur."

Mr. Hacket's observations are more conclusive, as he is intimately acquainted with the Vindhyans of the Gwalior country, with which he has no hesitation in ranking the rocks at Sojat. This locality is 50 miles to the east-south-east of Jodhpur, and separated by only 12 miles of alluvial flat from the western edge of the central range of the Arvalis, composed of metamorphic and transition formations. The little hill only covers about 1 square mile, and the whole thickness of the sandstone is less than 200 feet. The rock is not very hard; it is red at top and yellowish-white below, with a bottom bed of conglomerate resting flatly upon vertical schists. A couple of miles to the north of Sojat, but quite detached, there are some low hills of cherty limestone, the bedding of which is very obscure, but apparently horizontal; and Mr. Hacket is disposed to think that the rock is younger than the Sojat

[1] W. T. Blanford, Records, G. S. I., Vol. X.

sandstone, which has a gentle northerly slope. This limestone has a considerable extension to the north.

The condition in which the Vindhyans occur on the west side of the Arvali, much more than their state on the east side, proves them to be quite superficial as regards the rocks of the Arvali system, and that it is only in a secondary and derivative manner that they can be related to the Arvali mountain-system. Thus it is probably incorrect to speak of this Jodhpur sandstone as an outlier of the upper Vindhyan basin: it is more likely to be an independent representative of that formation. This interpretation implies that the Arvali axis is of pre-Vindhyan origin, and that altered Vindhyans do not form part of the Arvali rocks.

Allusion was made (p. 16) to some small Vindhyan outliers occurring on the Bundelkhand gneiss to the north and west. They differ much in character, and their peculiarities of composition may help to explain their apparently anomalous position. Although the gneiss reaches high up under the scarp of Kaimur conglomerate all round the western border of the area, which is described as a local edge of deposition, these small outliers occur at the level of the low country. If they agreed in composition with the rocks of the main area, which are so strikingly constant in this respect within that area, the fact might be at once explained by a subsequent change of level; but such is not the case.

The most curious of these outliers form a very broken chain running to south-south-east from close under the Pár scarp at Ládera (7 miles east of Antri) to Uchár on the Sindh river. Most of the exposures are quite level with the plain, or only to be seen in the beds of streams. In a few cases, as at Ládera and Pichor, they form narrow ridges up to 300 feet in height. The rock is sandstone of the upper Vindhyan type; and at the north end, close to the Pár scarp, it contains large angular pieces of the banded Morár shales; but elsewhere it is quite free from coarse debris of any kind. From many clear sections it is quite evident that these ribs of sandstone once filled a more or less continuous run of cracks, fissures, chasms, or small valleys in the gneiss. On both sides of the Pichor ridge the gneiss reaches well up on the sides of the sandstone mass, with vertical surfaces of contact. In the low ground at the point of the ridges, and in the small outliers, thin vein-like runs, 3 feet wide and upwards, of the sandstone, are well seen completely let in to the gneiss, as it might be filling an emptied trap-dyke, the rootlets of the wider chasm above. Even in the larger masses no bedding is visible; but sometimes at the edge of the mass planes of pseudo-lamination and even ripple-marked surfaces occur parallel to the vertical wall of gneiss. In every case observed, the lines of ripple were horizontal,

and the steep face of the ripple turned downwards. Some of these features seem to necessitate the supposition that the sandstone was let into this position by disturbance; but all the other circumstances have suggested the explanation given. The ripple may have been produced by dripping.

At Máharájpur, 10 miles south of Antri and 14 miles east of the Vindhyan scarp, there is a small group of hills, about 3 square miles in extent, formed of fine sandstone overlying about 50 feet of flaggy shales, both of Vindhyan type. The strata are greatly disturbed, but most irregularly, as if compressed from every side. Although so much broken, the rock is quite free from vein-quartz, which is also a general character of the Vindhyans as compared with the Gwalior strata.

The small hills of Sonár, 10 miles south-east of Narwar, and of Mohár, 16 miles farther in the same direction, present the same characters of composition and disturbance as at Máharájpur. At Mohár a trace of the Kaimur conglomerate occurs in the sandstone above the shales, which cover a considerable area round the base of the hill,[1] and may be looked upon as lower Kaimur.

A consideration of all the peculiar circumstances of these outliers would seem to suggest that they may represent small local basins of the upper Vindhyans. It seems that the process of denudation all round the Vindhyan area has been to decompose and remove the chemically-constituted metamorphic rocks which once formed high land around the sedimentary basins (whether this relation were original or due to subsequent warping of the surface), leaving the softer but undecomposable detrital rock to project where once had been depressions of the surface. This seems, indeed, to be a general law of denudation within appropriate limits and conditions.

[1] A remnant of the high-level rock-laterite occupies the summit of Mohár, but without any trace of trap. The importance of this observation will be shown in the chapter relating to laterite.

CHAPTER V.

PENINSULAR AREA.

GONDWÁNA SYSTEM.

Introductory remarks—Geological position and characters, and derivation of name — Area occupied — Fluviatile origin probable — Geological relations in India — Correlation with geological sequence in Europe and other countries — Contradictory evidence — Ancient zoological and botanical regions — Value of palæo-botanical evidence — Probable range of Gondwána system from permian to upper jurassic — Origin of Gondwána basins, and their relations to existing valleys — Surface of Gondwána area — Division of Gondwána system into groups — LOWER GONDWÁNA GROUPS — Tálchir group — Petrology — Boulder bed — Resemblance to volcanic rock — Resistance to weathering — Extent and thickness — Palæontology — Karharbári group — Reasons for distinguishing the group — Petrology — Relations to Tálchirs and thickness — Palæontology — Possible representation of group elsewhere — Damúda series — Sub-divisions — Palæontology — Relations to carboniferous flora of Australia — Relations to Karoo series of South Africa — Barákar group — Petrology — Relations to Tálchirs — Thickness — Ironstone shales — Rániganj group — Motur group — Bijori group — Kámthi and Hengir group — Mángli beds and their fossils — Panchet group — Petrology — Palæontology — Almod group.

Introductory remarks.—It has already been pointed out that there is, in the Peninsula of India, a remarkable deficiency of marine representatives of the palæozoic and lower mesozoic formations. Throughout the immense tract of land, bounded on the south by the sea, and on the north by the alluvial plain of the Ganges and Indus, there is, with the exception of the jurassic beds of Cutch (Kachh or Kach) and Jesalmir to the north-west, and a few outcrops of similar age along the east coast near Madras, Ongole, and Ellore to the south-east, no known marine deposit of older date than the cretaceous epoch.

Geological position and characters, and derivation of name.—The marine older and middle mesozoic, and probably the upper palæozoic formations of other countries are represented in the Peninsula of India by a great system of beds, chiefly composed of sandstones and shales, which appear, with the exception of the rocks just noticed along the east coast, to have been entirely deposited in fresh water, and probably by rivers. Remains of animals are very rare in these rocks, and the few which have hitherto been found belong chiefly to the lower vertebrate classes of

reptiles, amphibians, and fishes. Plant remains are more common, and evidence of several successive floras has been detected. The sub-divisions of this great plant-bearing series have been described under a number of local names, of which the oldest and best known are Tálchir, Damúda, Mahádeva, and Rájmahál, but the Geological Survey has now adopted the term Gondwána for the whole series. This term is derived from the old name for the countries south of the Narbada valley, which were formerly Gond[1] kingdoms, and now form the Jabalpur, Nágpúr, and Chhatisgarh divisions of the Central Provinces. In this region of Gondwána the most complete sequence of the formations constituting the present rock system is to be found.

Area occupied.—Taken as a whole, the Gondwána system has a wide extension in the Indian Peninsula; but its representatives have hitherto only been detected at one locality in Transgangetic India, *viz.*, along the base of the Himalayas in Sikkim, Bhután, and the Dafla hills.[2] Representatives of the highest Gondwána group are found in Cutch resting upon marine jurassic rocks and capped by neocomian beds; and in the desert which intervenes between Sind and Rájpútána, some rocks containing plant remains, and underlying jurassic limestones, closely resemble portions of the Gondwána series in lithological characters. Other representatives of beds high in the Gondwána series, in this case, however, frequently containing marine fossils, extend down the east coast. But with these exceptions, no representatives of the system are found in the Peninsula north of the line formed by the valleys of the Narbada[3] and Son, nor south-west of another line drawn from the sea at Masulipatam through Khamamet and Warangal north-east of Hyderabad, till it enters the trap area near Nirmal. The main areas of Gondwána rocks are in the Rájmahál hills and Damúda valley in Bengal, the Tributary Maháls of Orissa, Chhatisgarh, Chutia (Chota) Nágpúr, the upper Son valley, the Sátpúra range south of the Narbada valley, and the Godávari basin.

[1] For the information of non-Indian readers, it may be well to add that the Gond is one of the principal Dravidian, or so-called aboriginal, tribes, who are believed to have inhabited the country before the advent of the Aryan Hindu race.

[2] Mallet, Mem. G. S. I., Vol. XI, p. 1; and Godwin-Austen, J. A. S. B., 1875, XLIV, Pt. 2, p. 37. Perhaps the occurrence of a representative of the Rájmahál stratified traps on the flanks of the Khasi Hills might be quoted as a second instance. In this case, however, although the identification of the two sets of beds is highly probable, it has not been confirmed by the discovery of fossil evidence.

[3] Outcrops have been found in one place at least north of the river Narbada to the westward of Hoshangabad, but far south of the watershed. The Narbada, above the neighbourhood of Jabalpur, runs south of the general line of division, and Gondwána rocks occur north of the river.

Fluviatile origin probable.—It has already been mentioned that, with the few exceptions noted, the whole of the Gondwána series is believed to consist of strata deposited in fresh water, and the only question which arises is whether the beds are lacustrine or fluviatile. The coarseness of the rocks in general, the prevalence of sandstones, and the frequent occurrence of bands of conglomerate, render it improbable that these strata are of lacustrine origin, and the absence of mollusca almost throughout is, on the whole, rather more consistent with river than lake deposits, although it is difficult to account for on either hypothesis. The few fish and reptiles which occur might have inhabited either lakes or rivers, and the *Estheriæ*, which are common in several sub-divisions of the series, might either have lived in lakes or in the great pools and marshes which often occupy so large an area in broad river valleys. The plants might have been preserved amongst either lacustrine or fluviatile deposits, except that it is difficult to conceive the formation of beds of coal at the bottom of lakes; it is more probable that coal originated in marshy forests, such as frequently occur in the valley-plains of rivers. The physical characters of the strata, the frequent alternation of coarse and fine beds, the frequency of current-marking on the finer shales and of oblique lamination, due to deposition by a current, in the coarser sandstones, and the circumstance of the upper portions of a bed, such as a coal seam, being locally worn and denuded when a coarse sandstone is deposited upon it,—a phenomenon of frequent occurrence,—are quite consistent with the theory of deposition in a river valley, but opposed to the conception of lacustrine origin. A river constantly changes its course and deposits coarse sediment near its channel and finer materials from the overflow of its flood waters, the area within which each form of sediment is deposited varying frequently. In a lake the coarse deposits must be limited to the margin, and finer sediment accumulates away from the shore, whilst there is no current to sweep away the surface of a recently deposited coal or shale bed, and to throw down coarse sand in its place. On the whole, the evidence is decidedly in favour of a fluviatile origin for the Gondwána rocks, and it is probable that they were deposited in a great river valley, or series of river valleys, not unlike those which form the Indo-Gangetic plains at the present day. There is a possible exception in the lowest beds of the series, the fine silts which form the basement beds of the Tálchir group. These may be of lacustrine origin, but there is no clear proof that they are, and their remarkably persistent character throughout an immense tract of country is rather opposed to the idea of their having been formed in a lake or a series of lakes.

Geological relations in India.—Concerning the relations of this great series to older and newer formations but little can be said. No older fossiliferous deposits are known in the area to which the Gondwána rocks are restricted, and wherever these rest upon any older formation, there is complete unconformity between the two. With the upper Vindhyans, which are, in descending order, the next series in the Peninsula of India, the Gondwánas have nowhere been found in contact, the area occupied by the former being outside that to which the latter are restricted, but upper Vindhyan pebbles are occasionally found in Gondwána rocks. The Tálchir and Damúda formations in the country south of Nágpúr, on the Godávari below Sironcha, and in the Mahánadi valley near Sambalpúr, occasionally rest unconformably upon strata belonging to the lower Vindhyan series, but in general the Gondwána beds are found to have been deposited upon metamorphic rocks.

On the other hand, the rocks of the Gondwána series are but rarely covered at all by a higher formation, except in the Narbada valley and the Nágpúr country, where the Deccan traps and their associated infratrappean formation, the Lameta group, rest unconformably upon the various sub-divisions of the Gondwána series from the lowest to the highest. There are, however, localities in India in which sedimentary formations of cretaceous age rest upon upper Gondwána beds. The first of these is in Cutch (Kach or Kachh), where the Umia (Oomia) group, containing some fossil plants found also in the uppermost Gondwána beds in the Narbada valley, underlies a stratum containing *Cephalopoda* of upper neocomian (Aptian) age. The second is in the Narbada valley near Burwai, where Bágh beds (upper greensand or Cenomanian) rest unconformably on representatives of the Mahádeva formation (upper Gondwána). The remaining two localities are near the east coast; one is in Southern India, at Utatur north of Trichinopoly, where the plant beds containing Rájmahál fossils underlie the Utatur (Cenomanian) group, unconformably in places, but elsewhere with apparent conformity; and lastly near Ellore. Here also the upper Gondwána beds contain Rájmahál plants, and marine fossils of upper jurassic age occur in the higher layers, whilst the age of the strata resting unconformably upon the Gondwána strata is not equally well defined; the overlying beds consist of two fossiliferous bands, one underlying a flow of basalt, believed to belong to the Deccan trap series, the other interstratified between the lower basaltic flow and a higher one. The igneous beds, like the Deccan traps elsewhere, are believed to be of upper cretaceous age, but the fossils in the upper or intertrappean bed differ from those in the lower or infratrappean, and it has not hitherto been practicable to refer either to a

definite horizon. Neither bed, however, can be older than upper cretaceous.

Correlation with geological sequence in Europe and other countries.—The attempt to correlate the Gondwána series with the typical sequence of sedimentary formations in Europe has proved a long and difficult undertaking, and cannot even now be considered as definitely decided, although some light has been thrown upon it by the researches of Dr. Feistmantel, who is engaged in examining the fossil plants from the different Indian groups. He ascribes to the whole series an age ranging from lower trias or Bunter (Tálchir and Damúda) to middle jurassic or Bathonian (Jabalpur and Umia). His determinations, however, being founded exclusively on a comparison of the Gondwána fossil plants with those of European formations, are very frequently opposed by other fossil evidence. The Umia beds of Cutch, for instance, the flora of which is considered by Dr. Feistmantel of the same age as that of the Jabalpur group, which is the highest Gondwána sub-division, contains several plants found also in the lower oolites of Yorkshire, but the *Cephalopoda* of the marine beds which immediately underlie the Umia plant beds, and are to some extent interstratified, have been shewn by Dr. Waagen to be uppermost Oolite (Portland and Tithonian) forms, and to be separated by two distinct groups of beds, each with a well-marked fauna, from the underlying strata in which lower oolitic *Cephalopoda* occur. In the Damúdas and their representatives, on the other hand, although a few fossil plants are allied to triassic species, several of the most abundant and characteristic forms are unknown in the trias of Europe, but are represented by the same or nearly allied plants in the coal measures of Australia, the lower portion of which is certainly of carboniferous age.[1]

Contradictory evidence.—It is probable that the exact relation of the different groups composing the Gondwána series to rocks containing a similar flora in Europe and in other parts of the world will never be satisfactorily determined until the geology of the intervening regions is better known. As an example of the difficulties presented in the present state of our knowledge by the contradictory evidence afforded by the fossils of one group, the case of the Kota-Maleri beds may be cited.[2] The Kota beds consist of limestone, and contain remains of fish which have a liassic facies. The Maleri (or Maledi) beds have yielded two reptiles, *Hyperodapedon* and *Parasuchus*, and a fish, *Ceratodus*, all of which are closely allied to European triassic forms. In these Maleri beds, some

[1] For some additional details see p. 119. Further information as to the age of Gondwána beds will be found in Mem. G. S. I., Vol. II, p. 299; Vol. III, p. 197; Records G. S. I., IX and X, &c., &c.; and Q. J. G. S., 1855, p. 345; 1857, p. 325; and 1875, p. 519.

[2] For further details see pp. 151-156.

plants have been obtained common to the Jabalpur and Sripermatur groups, the flora of the former of which has been shewn to be in part identical with that of the Umia group of Cutch. The singularly contradictory evidence of age afforded by this Umia flora has already been mentioned. The Kota beds, with their liassic fish, have now been shewn to be so closely connected with the Maleri clays and sandstones, containing triassic reptiles and fish, and jurassic plants, that both are classed in the same group.

Ancient zoological and botanical regions.—Assuming that the association of similar marine forms in the rocks of distant countries—for instance, in the carboniferous limestone of Europe, the Punjab in India, and Australia—implies that the rocks are of contemporaneous or nearly contemporaneous origin, the remarkable combination of fossils in the Kota-Maleri beds appears to shew that, in mesozoic times, there was a wider diversity in the forms of terrestrial life inhabiting distant regions at any given period, than there was in the faunas of the surrounding seas. This view is in accordance with the very similar conditions now found prevailing upon the earth's surface, there being a much greater difference between the terrestrial faunas and floras of Africa, Australia, and America, for instance, than there is between the animals inhabiting the Atlantic, Indian, and Pacific Oceans. It is a common circumstance, moreover, to discover fossil remains of animals without any living representatives in neighbouring lands, but which are nearly allied to forms still existing in distant countries. Thus extinct genera of lemurs are found in the older tertiaries of Europe and North America, whilst the living forms of the order are restricted to Africa, Madagascar, South-Eastern Asia, and the Malay Archipelago. The genus *Ceratodus*, also, which is not rare in the older mesozoic strata of Europe, and the occurrence of which at Maleri has just been mentioned, has recently been found represented by living species in Australia. There appear, in short, good reasons for believing that the terrestrial area of the world was divided into zoological and botanical regions in past time, as it is at present, and the fauna and flora of India may have differed, at times, more from those then existing in distant countries, than from the animals or plants which prevailed in the same distant regions at a different geological epoch.

Value of palæo-botanical evidence.—At the same time, although it is unsafe to consider Indian formations of contemporaneous origin with those found in other countries on the evidence of their terrestrial flora or fauna alone, the remains of plants furnish most valuable evidence as to the representation of different groups by each other within the Indian area, because it is reasonable to suppose that the range in time of each species and genus in neighbouring countries was nearly the same. It is

consequently reasonable and safe to refer the Kota-Maleri beds to the same approximate horizon as the Jabalpur group, or to a slightly lower position, corresponding to that of the Sripermatur beds, although it is not safe to refer the Kota-Maleri group to the lower oolites on account of its plant remains, to the trias on the strength of its reptiles, or to the lias, because of the fish it contains.

It should, however, not be forgotten that plant remains are usually fragmentary, and they are but rarely so well preserved or so characteristic as remains of animals. The most important portions of the plant—those connected with fructification—are usually wanting, and the leaves and stems, which are most commonly found fossil, are far less characteristic, both because those belonging to different species or genera and even to different orders resemble each other closely in many cases, and also because leaves and stems are liable to great variation even in different parts of the same plant. A single fairly preserved molluscan shell, especially a Brachiopod or a chambered Cephalopod, one cup of a coral, or the test of an Echinoderm, and frequently a single tooth or bone of a fish, reptile or mammal, affords far safer indication of affinities than the leaf of a phanerogamous plant or the barren frond of a fern, however well preserved. But in all cases of this kind evidence is cumulative, and the probabilities in favour of identification increase in geometrical proportion with the number of forms. If one leaf or stem be found which appears to be the same as a species found elsewhere, we may fairly suspend our judgment, but our confidence in the identification increases rapidly when several leaves, for instance, belonging to different genera, found together in one formation, correspond closely to forms similarly associated in beds at a distance.

Probable range of Gondwana system from permian to upper jurassic.—Some details of the flora and fauna will be given with the general descriptions of the different groups. Taking the whole evidence into consideration, different writers on the affinities of the lowest Gondwána beds have assigned these formations to various epochs from carboniferous to lower triassic, and the highest Gondwánas have alternately been assigned to lower oolite and wealden. The truth may very probably lie between the two extreme opinions in each case. A slight, but very valuable, suggestion has been founded[1] on the evidence of ice action at the base of the whole Gondwána system, and on similar evidence in other countries, and especially in England, in rocks belonging to the permian period. Assuming, as it is perfectly justifiable to do, after the enormous accumulation of evidence now available, that the whole world has, in late geological times, passed through a cold period, it is not unreasonable to suppose that similar epochs of diminished

[1] H. F. Blanford, Q. J. G. S., 1875, Vol. XXXI, p. 528, &c.

temperature have recurred in past ages, and that one of these eras of glacial conditions coincided with the permian age. The singular poverty in organic life of the permian and lower triassic rocks throughout many parts of the world, and the extensive change which took place about this period in the fauna and flora, may be due, in part at least, to the occurrence of a great diminution in the temperature of the earth's surface. With this additional suggestion to support it, the reference of the lowest Gondwána strata to the permian epoch appears to agree better with the existing state of knowledge than any other, and it will be equally safe to class the Umia beds of Cutch as upper jurassic, the uppermost true Gondwána beds of Jabalpur being perhaps a little older. But it must not be considered that this determination of the age of the Gondwána series is final, for additional evidence may, and very probably will, lead to modifications. At present it is only practicable to select, from amongst a number of conflicting views, those which appear least in discordance with the evidence hitherto obtained.

Origin of Gondwana basins and their relations to existing valleys.—The manner in which the areas of Gondwána rocks are distributed throughout the country is peculiar, and there is still some difference of opinion concerning the interpretation to be placed on their mode of occurrence. As a general rule, these rocks are found occupying basin-shaped depressions in the older formations, and such depressions sometimes, though not always, nor even generally, correspond to the existing river valleys. Occasionally the basins of Gondwána beds are scattered over the surface of the country, as in Birbhum (Beerbhoom), and in this case there can be no doubt of their representing the undenuded remains of strata which were once continuous over a much larger area. Whether the basins now remaining owe their preservation to disturbance of their originally horizontal position, and to their having been preserved from denudation through having sunk to a lower level than neighbouring portions of the same bed, or whether they were originally deposited in hollows in the older beds, is a point on which opinions differ. There can be no question that the former is the explanation of these basins having been preserved in some instances; but cases may also be cited in favour of the latter view, and it is certain that the Gondwána beds were originally deposited on an uneven surface.

A few instances will suffice to shew the phenomena presented in the Damúda valley in Western Bengal, where some of the most important and best known Gondwána coal fields occur. A number of detached basins are found, all in low ground, on the banks of the river, and all presenting the very remarkable peculiarities that the lowest groups

appear on the northern side of the basin, that there is a general dip from north to south, and that all are cut off abruptly on the southern edge, which is in most cases along a straight or nearly straight line. Similar geological relations exist in many other areas, although the beds are not always, as in the Damúda area, confined to the valley of a single river. Thus, in the great basin of South Rewah and Sirgúja, again in the Sátpúra area, and especially in the Tálchir field in Orissa, the rocks dip from one side of the basin, and are cut off on the other; but in all these cases the general dip is north, not south, and the beds are abruptly cut off along the northern border. The exact direction of the abrupt east and west boundaries vary, but they are always the same, or nearly the same, throughout each tract of country: that is to say, the boundaries of different fields are parallel to each other, and they are also, as a rule, identical in direction with the foliation of the underlying gneiss. In some cases, and especially in the northern part of the great area which occupies so large a portion of the Godávari valley, both boundaries, which, in the last-named case, run nearly north-west to south-east, are straight, nearly parallel and abrupt.

These abrupt boundaries are almost invariably accompanied by considerable disturbance of the beds in their neighbourhood. In some cases there is strong evidence that such boundaries are great faults, one of the best proofs being that the fault occasionally divides, as along the northern edge of the Tálchir field, and beds belonging to the lowest group are exposed between the different sub-divisions of the main dislocation; the lowest Gondwána group (the Tálchir in the instance mentioned) being faulted against Kámthi beds, much higher in the Gondwána series, on one side, and against metamorphics on the other. In some cases, as along the boundary of the Tálchir field, and also on the eastern portion of the northern boundary in the Sohágpúr field, the line of fault is marked by a breccia, containing fragments of the Gondwána sandstones. It is considered by several of the Geological Survey that all the fields which are bounded by an abrupt line cutting them off on one or both sides (and these, as will be seen, comprise a very large majority of the basins known) occupy areas of depression produced, subsequently to the deposition of the beds, by a great fault along the abrupt boundary. It is further urged that the present connection of existing river valleys with these Gondwána areas depends upon the fact that the Gondwána rocks being much softer than the Vindhyan, transition, or metamorphic beds upon which they rest, the rivers have worn their way through the easiest channel; that, in short, the existing drainage, so far as it coincides with the distribution of the Gondwána rocks, has been determined by

the disposition of those rocks produced by disturbance and denudation, and has no necessary connection with their original areas of deposition.

A different view is held by others. They consider that there is, with a few exceptions, no sufficient evidence of faulting, that the appearance of straightness in the boundaries is partly fallacious and due to the rocks being ill seen at the surface, that the abrupt boundaries are caused by the deposition of the Gondwána rocks against cliffs forming the original sides of river valleys, and that the present disposition of the beds is a close approximation to that of the original areas in which they were deposited. They especially point out that in one instance, in the Sátpúra area, Gondwána rocks overlap the abrupt boundary in places. They consider further that the vertical development of the different groups varies so much within small distances, that there is no reason to believe that any great thickness of beds abuts against the abrupt cliff-like boundaries, and that there is evidence in some cases that the different groups thin out towards the margins of the existing basins. They conclude that the present river valleys differ but little from those which existed in mesozoic times.

It is possible that there may be some truth in both views. It should be remembered that the conflict of opinion in this case is between observers, who have chiefly been engaged in mapping widely-separated regions, the uniformitarian view, that the present basins closely correspond to ancient areas of deposition, being supported chiefly by observations made in the Sôn and Narbada valleys, and the opposite opinion, that the present Gondwána basins are chiefly due to faulting, being held by geologists who have especially studied the Gondwána rocks of Bengal, Orissa, and the Godávari valley. It is possible that there may be a difference in respect to the amount of disturbance undergone between the upper and lower Gondwána series: such a difference has been shewn, on very good evidence, to exist in Western Bengal, where trap dykes, supposed, with great probability, to be of upper Gondwána age, are newer than the dislocations affecting the lower Gondwána beds; and it is by no means improbable that a similar disturbance may have affected the lower members of the Gondwána system in other parts of India before the deposition of the uppermost groups. The strongest arguments against the existence of faults along the abrupt boundaries of the various Gondwána fields is founded on the fact, that in the Sátpúra field to the south of the Narbada valley certain of the uppermost Gondwána beds overlap the boundary; but this may be due to the circumstance that the supposed line of fault, which cuts off the field on the northward throughout the greater portion of its extent, is more ancient than the

topmost groups of the Gondwána series. One important observation in favour of the basins in the Damúda valley in Western Bengal having been disturbed and depressed to their present level subsequently to the period of their deposition, or, conversely, of the continuation of the same beds having been raised to a higher elevation, is to be found in the presence of Tálchir and Damúda beds on the Hazáribágh table-land, immediately north of the Damúda valley, at a height of about one thousand feet above the surface of the same rocks in the valley itself, and in the existence of fragments, apparently derived from lower Gondwána beds, in a conglomerate at a similar or higher elevation on the Chutia Nágpúr highland to the southward. Some of the abrupt boundaries to the south of the Gondwána basins in the Damúda valley, and especially the southern margin of the Karanpura and Bokáro fields, are shewn to be long lines of fault by independent evidence, which will be mentioned in the descriptions of those areas. Another difficulty in the way of admitting that the abrupt boundaries of the Damúda fields are due to deposition against inland cliffs is to be found in the improbability that all such precipices should be found on one side of a river valley—the south in this instance,—and none on the northern bank. It may be questioned whether anywhere amongst gneissose rocks such a series of straight and parallel cliffs can be found as must be supposed to have existed in the Gondwána epoch, along the southern side of the Damúda valley, if the abrupt southern boundaries of the various fields are to be explained otherwise than by faulting. At the same time, it is possible that the extent of the faults may have been unintentionally exaggerated by the surveyors who mapped the coal-fields, and that, owing to irregularities in the thickness of the various groups, the whole vertical extent of the beds, at any particular locality, may be less than was at first supposed. In the descriptions of the different fields to be given in subsequent pages, the views of the original describers will, to a great extent, be followed; but it must be understood that these views are not universally conceded, and that further examination of the ground may cause a considerable modification of the opinions hitherto held.[1]

Surface of Gondwana areas.—The tracts of country occupied by rocks of the Gondwána series are, as a rule, covered with a poor sandy soil

[1] It should, perhaps, be stated that the two authors of the present Manual hold different views in this matter; Mr. Medlicott believing that the present basins approximate closely in form to the original river valleys, whilst Mr. Blanford thinks that the present Gondwána areas are remnants of more extensive deposits preserved from denudation through being let down by faults. Both agree in considering that the Gondwána beds were originally river-deposits.

and ill suited for cultivation. The result is that in many parts of India they form wild uninhabited forests. Such tracts are always the last to be surveyed topographically, and, as a rule, minor details are omitted on the maps prepared. The upper Gondwána rocks are principally sandstones, and decompose into loose sand, which covers the whole surface of the country and greatly conceals the rocks. These two circumstances—deficiency of maps and concealment of the surface—have combined to delay the Geological Survey of the important Gondwána formations, and to render the examination of the beds exceptionally tedious and difficult.

Division of the Gondwana system into groups.—The groups of which the Gondwána system is composed vary greatly both in number and mineral character in the several isolated areas in which they are found, the variation being much greater amongst the middle and upper than amongst the lower members of the series. The two lowest Gondwána groups, Tálchir and Barákar, preserve their mineral character almost unchanged throughout the area in which the lower Gondwána beds are known to occur. The inferior sub-divisions of the system, the Tálchirs and Damúdas, consist largely of shales, whilst the uppermost formations are chiefly composed of coarse sandstone, grit, and conglomerate.

The system may be divided into an upper and a lower series; the Tálchir, Damúda, and Panchet groups, with their equivalents, being referred to the latter; the Rájmahál, Mahádeva, and Jabalpur to the former. The distinction is generally marked palæontologically by the prevalence of equisetaceous plants in the lower sub-division, and of cycads and conifers in the upper,[1] ferns being found commonly in both. Some *Equisetaceæ* occur, however, in the upper Gondwánas, and several species of cycads and conifers in the lower, but the genera are in most cases distinct in the two subdivisions.

In consequence of the variation which is exhibited by the members of this system, it is necessary to describe, in some detail, the characters presented in the different areas in which it is represented. This is also rendered desirable by the economic importance of the Damúda group, from which nearly all the coal extracted in India is obtained. The attention of the Geological Survey has, from its first commencement, been especially directed to the coal-producing beds and their associates, and, in consequence, a large number of the coal-fields have been carefully and systematically surveyed.

Before proceeding to these details, however, it will be useful to describe the groups, and to explain their names. The following table shews the principal groups represented in each area, and their representation of each other so far as their connections have hitherto been traced.

[1] The Mahádeva formation has, however, hitherto proved almost unfossiliferous.

Table shewing the supposed representation of Gondwána groups by each other.

	General sequence.	I. Rájmahál.	II. Birbhum, Deogarh, and Karharbári.	III. Damúda valley.	IV. Sôn, Mahánadi, and Bráhmani valleys.	V. Sátpúra region.	VI. Godávari valley.	VII. East Coast region.	Cutch.
Upper Gondwána.	Cutch and Jabalpur.	...	...	...	...	...	Chikiala ...	Tripetty ...	Umia.
		...	...	...	Jabalpur ...	Jabalpur ...		Sattavedu? ...	Katrol.
	Rájmahál and Mahádeva.	...	...	...		Bagra ...	Kota-Maleri ...	Ragavapuram and Sripermatur.	...
		Rájmahál ...	...	...	Mahádeva ...	Denwa ...		Golapilli ...	...
		Dubrájpur ...	...	Mahádeva ...		Pachmari ...	...	...	...
Lower Gondwána.	Panchet ...	...	...	Panchet ...	...	Almod? ...		...	...
		...	...	Raniganj ...	Kámthi (Hengir)	Bijori ...	Kámthi (including Mángli).	...	...
	Damúda ...	...	...	Ironstone shales	...	Motur ...		...	...
		Barákar ...	Barákar ...	Barákar ...	Barákar ...	Barákar ...	Barákar ...	...	...
	Tálchir ...	...	Karharbári ...	...	...	...	...	...	...
		Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	Tálchir ...	...	...

In proceeding briefly to consider these groups in detail, it is more convenient to commence with the oldest.

I.—LOWER GONDWÁNA GROUPS.

Talchir.—This group, which everywhere when present—and it is rarely absent over a large area—forms the base of the Gondwána series, was thus named from its having been first clearly distinguished in the small district of Tálchir,[1] one of the tributary mahàls of Orissa.

Composition and petrology.—The Tálchir group consists in general of fine silty shales and fine soft sandstone. The shales are usually of a greenish-grey or olive colour, sometimes slaty; they are of exceedingly fine texture and traversed by innumerable joints, and they break up into minute, thin, angular fragments, sometimes elongate or acicular, which cover the surface of the ground in places. Occasionally the shales have a dull Indian red colour, but this is not common. They are frequently mentioned in the Survey reports under the name of mudstones and needle-shales; not unfrequently they are somewhat calcareous, and in places large concretionary masses of impure carbonate of lime have been found amongst them.

The most characteristic sandstones are soft, fine, and homogeneous in texture, composed chiefly of quartz and *undecomposed* pink felspar, and are pale greenish-grey, buff, or pale pinkish, almost of a flesh tint. They are frequently rather massive, though distinctly stratified, but they are also commonly interstratified in thin layers with the shales. In many places they break up on the surface, where exposed, into polygonal fragments 3 or 4 inches in diameter; hence they have been called tesselated sandstones.

These beds pass into coarser sandstones of less marked character, which are sometimes, though rarely, conglomeratic, and which vary in colour. It is an almost invariable rule, contrary to what is found to be the case in most rocks, that in the Tálchir group the beds of finest texture, the shales, are found at the base, and that the sandstones are higher in position; the coarser sandstones, moreover, overlying those of finer texture. A thin coal seam has been found amongst the Tálchir beds in the Jhilmilli field, in Sirgúja, but, as a rule, this formation is distinguished by the absence of coal seams, and even of carbonaceous shale.

There are three peculiarities of the Tálchir group which still require notice, as all of them are of considerable importance.

Boulder bed.—The first is the frequent occurrence, amongst the shales and fine sandstones, generally towards the base of the group, but very

[1] Mem. G. S. I., I., p. 46.

frequently some hundreds of feet above the bottom, of pebbles and boulders, always rolled and usually well rounded, varying in size from small fragments half an inch or an inch across to huge blocks 15 feet in diameter and 30 tons in weight; fragments from 6 inches to 8 feet in diameter being common. The distribution of the boulders is most irregular; in some parts of the area occupied by Tálchir beds, none are to be found over many square miles of country, but generally some are met with at intervals, and occasionally large numbers occur within a limited tract.

In very many instances there is every probability that the boulders have been transported from a distance, no rocks of similar character being found in the neighbourhood. If only one or two such cases had been observed, it might be supposed that the rock from which the blocks were derived had formerly existed in the immediate vicinity, but had been removed by denudation; the cases, however, in which there is reason to believe that the rounded blocks have been transported from afar are so numerous that the theory of denudation cannot be accepted. The boulders, it should be remembered, are frequently found imbedded in the finest silt. It is evident that deposition from water in rapid motion is here out of the question; any stream which could move and round the boulders would have swept away the silty matrix in which they are deposited, and the only suggestion as to the cause of their occurrence which appears satisfactorily to account for their presence is to suppose that they have been originally rounded by torrents and then transported to their final position by ground ice. This theory has received strong confirmation by the discovery of smoothed and scratched surfaces on some of the large boulders found on the banks of the Pem River, about 10 miles west-south-west of Chánda, Central Provinces.[1] The surface of the lower Vindhyan limestone rock underlying the Tálchirs was also in this case found to be polished, scratched, and grooved.

Resemblance to volcanic rocks.—The second peculiarity is the remarkable resemblance to a volcanic rock occasionally presented by the more compact forms of shale and by a variety of the sandstone. So great is the similarity between the shale and a consolidated volcanic ash that two experienced surveyors have at different times marked the beds as trappean, whilst the sandstone occasionally simulates a decomposed basalt in colour and mode of weathering.

Resistance to weathering.—The third noteworthy feature of the Tálchir beds is their power of resisting disintegration, and, provided of course they are not covered by alluvial deposits derived from other rocks,

[1] Oldham, Mem. G. S. I., IX, p. (324); Fedden, Rec. G. S. I., VIII, p. 16. The question of the origin of the Tálchir boulder bed is discussed in the Memoirs, *l. c.*

the extreme barrenness of the ground, where they appear at the surface, is a natural consequence of their not decomposing to form soil. In many places along the edges of the coal-fields, where the Tálchir beds occupy the ground, it is possible to walk for miles through very thin jungles, free from grass, over a surface composed entirely of the finely comminuted greenish-grey shales.

Extent and thickness.—The Tálchirs preserve all their peculiarities throughout the area in which they occur; this is an enormous tract of country, extending from the flanks of the Rájmahál hills to the Godávari, and from the Rániganj field on the borders of the alluvium of Lower Bengal to the neighbourhood of Hoshangabád, Nágpúr, and Chánda.

The thickness of the Tálchirs nowhere appears to exceed about 800 feet, their extreme measurement where fully developed in part of the Rániganj coal-field.

Palæontology.—The fossils[1] hitherto discovered in the Tálchir rocks are very few in number. Of animal remains only the wing of a neuropterous insect and some annelide tracks have been discovered, whilst the plant remains consist of three ferns, *Gangamopteris cyclopteroides*, *G. angustifolia*, and a form of *Glossopteris*, represented by a single fragment, some equisetaceous stems, and a plant, hitherto not distinctly identified, resembling *Noeggerathia*[2] *hislopi*. The only evidence of vegetable life hitherto found has been in the higher beds of the group, and there is a remarkable absence of plants in the lower shales, which are admirably suited for preserving vegetable impressions. Even in the upper beds of the group fossils are of singularly rare occurrence.

Probable conditions of deposition.—Reference has already been made to the possibility of a lacustrine origin for the Tálchir beds, or at least for the lower portion. The chief reason for suggesting that these beds may have been deposited in lakes is the great thickness of very fine sediment accumulated at the base of the group, and the very frequent occurrence of much finer beds below than above. The latter, on the hypothesis of a lacustrine origin, may be explained by the gradual silting up of a lake basin, in which fine sediment would be deposited at a distance from the margin, whilst coarser beds would be thrown down by rivers as their deltas advance into the lake and fill it up. This evidence, however, is quite insufficient alone to prove that the Tálchirs are a lacustrine deposit,

[1] The fossil plants occurring in this and other groups of the Gondwána system have been chiefly determined by Dr. Feistmantel.

[2] The species here and elsewhere called *Noeggerathia* are, in all probability, not congeneric with the type of that genus, a carboniferous plant. They have lately been referred to *Zamia* by Dr. Feistmantel, but as this reference to a living genus is temporary, it is perhaps as well for the present to preserve the original generic name.

and it is at least equally probable that they were formed in a river valley like the overlying members of the Gondwána series.

To account for the climatal conditions which, in a tropical country, could be consistent with the occurrence of winter cold sufficiently intense to cause the formation of ground ice, it has been suggested that the Tálchir beds were formed on a lofty plateau like that of Tibet. The chief obstacle to the acceptance of this hypothesis is the difficulty of believing that a change in elevation, sufficient to account for the absence of all glacial conditions in the overlying Barákars, could have been effected without a much greater amount of disturbance than has taken place between the deposition of the two groups. The occurrence,[1] in rocks occupying the same approximate position at the base of the South African representatives of the Gondwána series, of similar boulder beds, which by some writers are attributed to ice action,[2] the suggestion of a like origin for the breccias of the English permian rocks,[3] which are probably of the same age, and the probability that the whole globe may have passed through a period of low temperature at the close of the palæozoic epoch, have already been mentioned.[4]

Karharbari Group,—Reasons for distinguishing the group.—Hitherto, in the publications of the Geological Survey, the coal-bearing rocks of the Karharbári coal-field have been assigned to the Barákar group, on account of their mineral character and their position immediately above the Tálchir beds. The examination of the Karharbári fossil flora has, however, shewn that whilst all the species, known to be found in the Tálchir beds, are represented, one of them, *Gangamopteris cyclopteroides*, being the commonest fossil of the Karharbári beds, many of the common Damúda fossils are rare or wanting, and several very remarkable species are found which have not hitherto been detected in the Damúda series. The peculiar excellence of the coal and its superiority to that obtained from the majority of the Damúda seams, have led to extensive mining operations in the Karharbári field, and it has consequently been possible to obtain good collections of the fossil plants.[5] It has also been noticed that the coal of Karhar-

[1] Mem. G. S. I., IX, p. (325), 31; Q. J. G. S., 1875, p. 529, &c.

[2] Sutherland, Q. J. G. S., 1870, p. 514; Griesbach, Q. J. G. S., 1871, p. 58. By other writers, however, this rock is said to be volcanic (Q. J. G. S., 1867, pp. 142, 172); but it is difficult to reconcile this view with the account given by Dr. Sutherland and Mr. Griesbach The latter writer suggests that two distinct rocks—a melaphyr and the boulder bed proper —have been confounded.

[3] Ramsay, Q. J. G. S., 1855, p. 185.

[4] H. F. Blanford, Q J. G. S., 1875, pp. 530, &c.

[5] These have been chiefly collected by Mr. I. J. Whitty, Superintendent of the East Indian Railway Company's collieries at Karharbári.

bári differs in structure from that of the Damúda series generally, and a partial re-examination of the field appears to justify the inference that there is also a slight distinction between the Karharbári and Barákar sandstones, although it is as yet uncertain whether a passage may not eventually be found between the Karharbári group and the Barákars. The palæontological evidence hitherto obtained tends, however, to connect the former with the Tálchir group, and it appears best, for the present, to keep the rocks of Karharbári distinct from the overlying Damúda series, under the name of the coal-field in which alone they are known to occur.

Petrology.—The rocks of the Karharbári group consist almost solely of sandstones, grits, and conglomerate, with seams of coal. Very little shale occurs, the little which exists being associated with the coal-seams. The sandstones are mostly white, grey, or brown, and felspathic; they are often gritty and conglomeratic from containing large fragments of felspar and pebbles of quartz. The chief distinction between the constituents of the grits and conglomerates forming the Karharbári group, and those which make up so large a portion of the Barákars, is that in the former, and especially in the coarser grits and conglomerates, a large proportion of the fragments of felspar and quartz are angular or subangular, whereas in the Barákars the pebbles are, as a rule, particularly well rounded. The coal of Karharbári is rather dull-coloured and tolerably homogeneous in structure, the layers of very bright jetty coal, which are so conspicuous in the Damúda seams in general, being few and ill-marked. So far as mining has hitherto proceeded, the coal-seams appear to be somewhat variable in thickness, but to undergo very little change in composition throughout the small field in which they are found, and of which a description will be given on a future page. Some of the seams, both in the Barákar and Ránigani sub-divisions of the Damúda series, furnish fuel equal in quality to that extracted at Karharbári, but they are much more distinctly laminated.

Relations to Talchirs and thickness.—The Karharbári beds rest in apparent conformity on the Tálchirs, but the former completely overlap the latter in places within the limits of the little Karharbári field, and the mineral characters of the two groups are strongly contrasted. In the west of the Karharbári basin the Tálchirs attain a thickness of about 500 or 600 feet, whilst within a distance of less than 4 miles to the eastward, the Karharbári beds rest upon the gneiss. It is probable that the highest rocks seen within the coal-field may be of Barákar age, and there is some slight appearance of the Karharbári beds being overlapped by these higher strata, but the overlap is not clear. The whole thickness of the Karharbári group is probably about 500 feet.

Palæontology.—The only fossils hitherto procured from the Karharbári group consist of plants. The following species have been identified[1]: the most abundant are indicated by a †; those marked thus § are found also in the Tálchirs; the species thus marked|| in the Damúdas.

EQUISETACEÆ—

|| *Vertebraria indica.*—Very rare.
Schizoneura, sp. near *S. meriani.*

FILICES—

† *Neuropteris valida.* Pl. VI, fig. 5.[2]
§ † *Gangamopteris cyclopteroides.* Pl. III, fig 1.
§ *G. angustifolia* and two other species of *Gangamopteris.*
|| *Glossopteris communis.*
G. decipiens.
Sagenopteris stoliczkana.

CYCADEACEÆ—

Glossozamites stoliczkanus.
|| *Noeggerathia (Zamia) hislopi,* var.
N. (Zamia), sp.
A peculiar genus, unnamed.

CONIFERÆ—

† *Voltzia heterophylla,* Pl. VI, fig. 7.
Albertia, sp. near *A. speciosa.*

The relations of this flora to the lower triassic or Bunter (*Grès bigarré*) flora of Europe are very well marked. *Voltzia heterophylla* and *Albertia speciosa* are characteristic Bunter species: the Karharbári plant is not specifically identical with the last form, but it appears to be nearly allied. The *Neuropteris* also belongs to a section of the genus with simply pinnate fronds, and this section is characteristic of lower triassic beds in Europe. The *Schizoneura*[3] is said to be near *S. meriani* (*Equisetum meriani,* Bgt.), an upper triassic species. The only other plant which has important affinities with members of the European fossil flora is *Glossozamites stoliczkanus,* belonging to a genus which in European strata ranges from lias to cretaceous.

Gangamopteris angustifolia appears to be identical with a plant described by McCoy[4] from the Newcastle coal-measures in New South Wales (palæozoic) and from beds in Victoria (Australia), the age of

[1] Feistmantel, Rec. G. S. I., IX, pp. 75, 76; X, p. 137.

[2] The plates for the present work had unfortunately been printed before the distinction between the Karharbári group and the Damúda series had been recognised, and consequently the figures of Karharbári plants have been mixed up with those of Damúda species.

[3] *Schizoneura gondwanensis* has been found in the Karharbári field in the uppermost beds (Rec. G. S. I., X, p. 138), but other plants since found in the same beds are Damúda species, and it appears probable that the strata in which *S. gondwanensis* occurs must be classed as Barákar.

[4] Am. Mag. Nat. Hist., 1847, Ser. 1, XX, p. 148.—Prod. Pal. Victoria, Dec. 2, Pl. XI.

which is not clearly determined, but which are probably lower mesozoic. *Glossopteris communis*, also, is allied to *G. browniana*, one of the characteristic fossils of the carboniferous rocks in New South Wales.

It has already been stated that all the known Tálchir plants are represented in the Karharbári group. On the other hand, there are in the above list only three forms—*Glossopteris communis, Vertebraria indica,* and *Nœggerathia hislopi*—common to the Damúda flora, and all these appear to be much less abundant in the Karharbári group than *Gangamopteris cyclopteroides*. It necessarily follows that, so far as the flora is concerned, the affinities of the Karharbári group to the Tálchir formation are stronger than to the Damúda series, because all the Tálchir plants that can be identified are found in the Karharbári group, whilst only a small percentage of Damúda forms appear to be represented.

Possible representation of group elsewhere.—The discovery that the Karharbári group differs both in mineral character and fossil flora from the lower beds of the Damúda series is so recent that it has not been possible to ascertain whether any representative of the Karharbári beds can be traced at the base of the Barákar, in the Rániganj and other coal-fields of the Bengal area, but the coal in a seam lying very little above the Tálchir group in the Ránigan field appears to resemble Karharbári coal in mineral character, and it is far from improbable that further research may shew the present group to have a wider distribution than has hitherto been ascertained.[1]

Damuda series.—The economical importance of the present series has already been noticed. Nearly all the coal-fields of the Indian Peninsula owe their mineral wealth to the presence of Damúda beds, the Kaharbári being the only other important coal-bearing group, and the quantity of valuable minerals contained in the rocks of the present series is probably greater than that known to occur in all the other rock groups of India together. The name Damúda is derived from a river in Western Bengal,[2] on the banks of which some of the richest coal-fields in the country are situated.

Sub-divisions.—The Damúda series has been found to consist in Bengal of three sub-divisions, known in ascending order as Barákar beds, Ironstone shales, and Ránigan beds. The first and lowest is also found in the Son, Mahánadi, Narbada, and Godávari valleys, the upper sub-divisions being represented by groups differing in mineral character from the Bengal beds. In the Sátpúra area the Damúda sub-divisions are known as the Barákar, Motúr, and Bijori groups; and in the Godávari valley, above the Barákar group, there, as in the Sátpúra basin, the only

[1] See foot-note to p. 217. | [2] J. A. S. B. 1856, XXV, p. 253.

coal-bearing formation, a single member of the upper Damúda beds occurs, and is known as the Kámthi group. A similar arrangement prevails in the Mahánadi and Bráhmini area, only two Damúda sub-divisions being found, which appear to correspond to those of the Godávari region.

The mineral characters and geological relations of all these different groups must be described separately: it is sufficient for the purpose at present to note that all consist of sandstones and shales with more or less ferruginous bands, and that some contain coal. Slight unconformity between the different groups has been noticed in places, and the Barákar beds are frequently unconformable to the Tálchirs. The whole thickness of the Damúda series is 8,400 feet in the Ràniganj field, and about 10,000 feet in the Sátpúra basin. It thus constitutes the most important portion of the Gondwána system.

Palæontology.—So far as the examination of the fossils, chiefly plants, obtained from the Damúda series, has progressed hitherto, there appears to be but little difference between the floras of the various groups, several species, including most of the commonest forms, being certainly found both in the upper and lower sub-divisions. It is therefore best to treat the palæontology of the series as a whole, to give a general list of the animals and plants hitherto recognised, which are far from numerous, and to treat of the affinities exhibited by the whole assemblage of forms to the fossil fauna and flora of other countries. The subject, as will be seen, is one of unusual interest and remarkable perplexity.

Taking the series as a whole, the following is a list of the fossils hitherto determined from it,[1] the more common and widely distributed forms being indicated by †.

[1] The following Tálchir, Karharbári, and Damúda fossil plants are figured on Plates III, IV, V, and VI:—

Plate III,	fig.	1.—*Gangamopteris cyclopteroides.*
„	figs. 2,	3.—*Sphenophyllum speciosum.*
„	fig.	4.—*Phyllotheca indica* (stem).
„ IV,	fig.	1.—*Schizoneura gondwanensis.*
„	„	2.—*Vertebraria indica.*
„	„	3.—*Schiz. gondwanensis* (stem).
„ V,	figs. 1, 2,	3.—*Phyllotheca indica.*
„	fig.	4.—*Glossopteris indica.*
„	„	5.—*G. retifera,* Fstm. sp. nov.
„	„	6.—*G. angustifolia.*
„ VI,	fig.	1.—*Vertebraria indica.*
„	„	2.—*Sphenopteris polymorpha.*
„	„	3.—*Macrotæniopteris danæoides.*
„	„	4.—*Alethopteris lindleyana.*
„	„	5.—*Neuropteris valida.*
„	„	6.—*Noeggerathia hislopi.*
„	„	7.—*Voltzia heterophylla.*

ANIMALS.

CRUSTACEA—

Estheria mangaliensis.

VERTEBRATA—

Archegosaurus ? (a Labyrinthodont amphibian).
Brachyops laticeps (ditto).

PLANTS.

EQUISETACEÆ—

† *Schizoneura gondwanensis.* Pl. IV, figs. 1, 3.
† *Sphenophyllum speciosum* (*S. trizygia*, Unger). Pl. III, figs. 2, 3.
† *Phyllotheca indica*, and numerous equisetaceous stems. Pl. III, fig. 4; Pl. V, figs, 1, 2, 3.
† *Vertebraria indica* (probably equisetaceous, but of somewhat doubtful nature). Pl. IV, fig. 2; Pl. VI, fig. 1.

FILICES—

Actinopteris bengalensis.
Sphenopteris polymorpha. Pl. VI, fig. 2.
Dicksonia, sp. near *D. concinna.*
† *Alethopteris lindleyana.* Pl. VI, fig. 4.
A. conf. whitbyensis.
A. phegopteroides.
Tæniopteris (*Angiopteridium*), sp.
† *T.* (*Macrotæniopteris*) *danæoides.* Pl. VI, fig. 3.
T. (*M.*) *feddeni.*
Palæovittaria kurzi.
† *Glossopteris browniana.*
† *G. indica* (*G. browniana* var. *indica*, auct.). Pl. V, fig. 4.
† *G. communis.*
G. angustifolia. Pl. V, fig. 6.
G. leptoneura.
G. musæfolia.
G. stricta, and several other species of *Glossopteris.*
G. retifera, Fstm. MS. Pl. V, fig. 5.
Sagenopteris pedunculata (*Glossopteris acaulis.*, McClel.).
S. polyphylla.
Gangamopteris whittiana.
G. hughesi.
Belemnopteris woodmasoniana.

CYCADEACEÆ—

† *Noeggerathia* (*Zamia*) *hislopi.* Pl, VI, fig. 6.
N., sp. near *N. vogesiaca.*
Pterophyllum burdwanense.

CONIFERÆ—

Stems, one of which has been referred with doubt to *Palissya.*

Excluding the forms from the Mángli beds, the only animal fossil hitherto known from the whole series is the *Archegosaurian* from the

Bijori beds of the Sátpúra basin, and as this has not been carefully compared and described, its affinities are somewhat doubtful.

The plant fossils have an unmistakeably mesozoic facies, and are considered by Dr. Feistmantel[1] to represent the Bunter group, the lower sub-division of the European Trias. This view, however, was in a great measure founded upon the relations of the plants found in the Karharbári beds, hitherto classed as Barákars, the only form in the above list which is distinctly triassic being *Schizoneura gondwanensis,* the nearest ally of which is the European *S. paradoxa,* found in the lower trias of the Vosges. Other plants are allied to European upper triassic or rhætic plants, as in the case of the *Actinopteris* and of the *Noeggerathia,* allied to *N. Vogesiaca;* whilst others, again, as *Phyllotheca, Alethopteris lindleyana,* and *Sagenopteris,* have their nearest allies in European beds amongst jurassic forms, *Sagenopteris* being also rhætic. The *Dicksonia* is closely allied to a Siberian oolitic species. *Sphenophyllum,* on the other hand, is a devonian and carboniferous genus, but the Damúda species differs somewhat from the European palæozoic types. *Noeggerathia hislopi* resembles some carboniferous forms almost if not quite as nearly as it does any mesozoic species, whilst the species of *Macrotæniopteris* are related to plants found in various European formations, from permian to jurassic. It is clear, however, that the flora as a whole, so far as it is at present known, has no resemblance to any definite assemblage of plants found in European rocks. The facies is perhaps older mesozoic, but, so far as can be seen, it might be either triassic or jurassic.

The chief peculiarity of the Damúda flora is the abundance of ferns with simple undivided fronds, and especially of the forms with anastomozing venation,—that is, with veins forming a net-work. To this last group belong *Glossopteris, Gangamopteris, Sagenopteris,* and *Belemnopteris,* comprising altogether thirteen species out of the twenty-two ferns, and thirty species of plants altogether, included in the preceding list. When to the thirteen forms already mentioned are added the three species of *Tæniopteris* and one of *Palæovittaria,* having simple fronds and parallel venation, the ferns with undivided leaves will be found to compose more than half the known flora. Nor is this all, for the genus *Glossopteris* especially is remarkable for the abundance of individuals as well as of species, so that it is the characteristic fern-genus of the formation. The simple-leaved ferns are certainly more abundant in mesozoic than in palæozoic rocks in Europe, but still they never prevail to the same extent as in the Damúda series. The only plants, besides ferns, which are of common

[1] Rec. G. S. I., IX, p. 68, &c.; Geol. Mag 1876, p. 491.

occurrence, are *Equisetaceæ*, stems of which, supposed to belong to *Phyllotheca*[1] and *Schizoneura*, are met with in great abundance, whilst *Vertebraria*, which is probably the root of an equisetaceous plant, is as common and characteristic as *Glossopteris*. Cycads and conifers are scarce.

Now, although several forms of the Damúda flora have a mesozoic aspect, the prevalence of ferns and *Equisetaceæ*, and the extremely subordinate share borne by gymnospermous exogens, are palæozoic characters. It would be unreasonable, however, to insist upon this point, because it is impossible to say how far the relative distribution of different classes of plants may have been due to climate. The important point is to call attention to the wide diversity between the composition of the Damúda flora and that found in any European formation.

Relations to carboniferous flora of Australia.—In Australia, however, there is a series of plant-bearing beds[2] which appear closely to resemble those of India in two points, the paucity of marine animal remains throughout the greater portion of the series, and the prevalence in particular beds of the genus *Glossopteris*, associated, as in India, with *Vertebraria* and equisetaceous stems closely resembling some of those found in the Indian coal-fields and referred to the genus *Phyllotheca*. *Gangamopteris* is also met with. The remarkable point is, that some of the commonest plant fossils of the Indian coal-fields, *Glossopteris*, *Phyllotheca*, and *Vertebraria*, are also those most abundantly represented in Australia, and that neither *Glossopteris*, *Gangamopteris*, nor *Vertebraria* has hitherto been found in mesozoic or palæozoic European rocks, whilst *Phyllotheca* is rare, being only known in Europe from the oolites of Italy.[3]

The following is the succession of beds in the coal-fields of New South Wales, where the series appears, so far as it has been described, to be more complete than in other parts of Australia and Tasmania, and where more attention has been devoted to the rocks.

[1] Dr. Feistmantel (Rec. G. S. I. IX, p. 70; J. A. S. B. 1876, pt. 2, p. 347, note, &c., &c.) has referred the greater portion of these stems to *Schizoneura*, but leaves of *Schizoneura* are local, although abundant in certain beds near the top of the Damúda series, whilst the equisetaceous stems are generally distributed. It is not impossible that some, of these fluted stems may belong to other equisetaceous forms besides *Phyllotheca* and *Schizoneura*.

[2] The best general account of the New South Wales coal formations is contained in a paper by the Rev. W. B. Clarke, Q. J. G. S., 1861, p. 354. See also Daintree, Q. J. G. S., 1872, p. 288, &c.; and Clarke, Mines and Mineral Statistics of New South Wales.

[3] A species has recently been described from beds in Siberia, said to be of jurassic (Bathonian) age. Heer, Flora fossilis arctica, IV, p. 43, pl. IV, f. 1-7. Heer, *l. c.*, considers *Equisetum laterale* from the lower oolites of Yorkshire a species of *Phyllotheca*.

Groups.	Fossils.
1. Wyanamatta beds	*Pecopteris odcntopteroides*, *P. tenuifolia*, *Odontopteris microphylla;* no *Glossopteris* is found.
2. Hawkesbury beds	*Palæoniscus* and several other genera of ganoid fishes with palæozoic affinities.
	N. B.—The plants are found in the Wyanamatta beds, the fish, chiefly, in the Hawkesbury group, but one fish is said to be common to both.
3. Upper coal-measures of Newcastle without marine fossils.	*Pecopteris odontopteroides*, *Alethopteris australis*, *Sphenopteris alata*, and several other species of *Sphenopteris*. *Glossopteris*, several species, especially *G. browniana*, *Phyllotheca*, *Vertebraria*, coniferous plants, *Noeggerathia*,[1] &c. *Urosthenes australis*, a heterocercal-tailed ganoid fish, allied to the carboniferous genus *Pygopterus*.
4. Lower coal-measures with marine fossils.	*Glossopteris browniana*. *Phyllotheca* and *Noeggerathia* are also stated to occur in these beds. *Spirifer*, *Productus*, *Conularia*, *Orthoceras*, *Fenestella*, &c., &c.
	N. B.—The marine fossils, which are typically carboniferous forms, are found in beds overlying and underlying shales and coal with *Glossopteris*, &c.
5. Lower carboniferous or Devonian.	*Lepidodendron nothum*, *Syringodendron dichotomum* (*Cyclostigma kiltorkense*), *Rhacopteris*, *Sphenophyllum*, &c.

Of the carboniferous age of the lower coal-measures, No. 4, there is no question. They are unconformable to the beds No. 5, with a true lower carboniferous flora, but are said to be conformable to the upper coal-measures, No. 3. On the other hand, it is asserted (though not by Australian geologists) that there is a marked distinction between the floras of No. 4 and No. 3, although one species, *Glossopteris browniana*, abounds in both, and, judging from the accounts of all Australian geologists, the genera of plants which prevail in the lower beds, No. 4, are also found in the upper, No. 3. In the same manner No. 1, the Wyanamatta group, is connected with No. 3 by the presence in both of *Pecopteris odontopteroides*, precisely as the Panchet beds in India are connected with the Damúdas by the occurrence in both of the same species of *Schizoneura*, but most of the Wyanamatta plants are distinct from those of the Newcastle coal-beds.

One most important point is the occurrence throughout the upper beds of the New South Wales coal-field of ganoid fishes, belonging to the genera *Palæoniscus*, *Chlithrolepis*, and *Myriolepis*. These are characteristically palæozoic types, although a few allied forms range into the lowest mesozoic rocks. But a selection of fossil fishes from the highest beds of the New South Wales series, the Wyanamatta group or beds immediately underlying it, has been examined by Sir P. Egerton, one of the highest

[1] See foot-note, p. 111.

living authorities, and considered by him to have a permian facies. At the same time, the curious case of the Kota-Maleri beds shews that even remains of fish, characteristic as they usually are, are not conclusive proof of exact age.

The greatest amount of similarity exists between the Damúda beds and the upper or Newcastle coal-measures of New South Wales, No. 3. The latter contain several species of *Glossopteris, Alethopteris, Sphenopteris, Phyllotheca, Vertebraria,* and *Noeggerathia,* closely allied to the forms found in the Damúda beds. Hitherto no Damúda plants are known to occur in the Wyanamatta and Hawkesbury beds; on the other hand, the genera of plants said to be found in the lower coal-measures of New South Wales, *Glossopteris, Phyllotheca,* and *Noeggerathia,* are also found abundantly in the Damúdas of India, and one species at least—*Glossopteris browniana*—is common to the two; but the other Australian fossils have not hitherto been examined in sufficient detail to enable their relations to be determined with certainty.

This much, however, is certain, that the whole fossil flora of the Australian beds, with the exception of the lower carboniferous or devonian flora No. 5, has just as distinctively a mesozoic facies, when compared with European plant fossils, as has the flora of the Damúdas and other lower Gondwána groups of India, and that the plants of the beds inter-

[1] Q. J. G. S. 1864, XX, p. 1, and Mines and Mineral Statistics, 1875, p. 176. In several papers published by Dr. Feistmantel for the purpose of proving that the Damúda beds are triassic, some of the South Australian plant beds are noticed as clearly mesozoic. None of these beds—not even the asserted jurassic strata of Victoria—are known to be newer than the Wyanamatta group of New South Wales, and the animal remains in the latter are palæozoic. In fact, except the plants, there is little or no evidence to shew that any of the Australian plant-bearing beds, except one group in Queensland, are mesozoic, and many palæontologists are disposed to doubt the value of plant evidence when opposed to the clue to age afforded by animal remains. It is highly probable that some of the upper Australian plant beds are contemporaneous with the lower mesozoic of Europe, and it is almost certain that the Newcastle beds of New South Wales with their equivalents in Tasmania and elsewhere must be classed as palæozoic. This, at least, appears the most probable view, and it has commended itself to some of the best European geologists. To assert, as some writers have done, that various Australian forms of plants—*e. g., Vertebraria* and *Phyllotheca*—are found in typically mesozoic beds, is to beg the question at issue.

The important fact is this: Of the fossils from the upper and lower coal-measures of New South Wales, Nos. 3 and 4 of the above list, which, by the testimony of numerous competent observers, are perfectly conformable and contain a very similar flora, only a few forms are sufficiently known for comparison. Of these few forms a large percentage—certainly more than one-half—are either identical with Damúda species or closely allied. There is no such connection between the flora of the Damúda and that of any European formation whatever. There is, however, a similar connection between the flora of the South African Karoo beds and the plants of both the Damúdas in India and the Newcastle beds in Australia.

stratified with the carboniferous marine fossils have been classed as mesozoic and even as jurassic by eminent palæo-botanists, and this so positively that the observations of the geologists, to whom we are indebted for our knowledge of the Australian rocks, was doubted for years until confirmed by the repeated testimony of several independent observers. On the other hand, the whole fauna of the Australian beds, so far as it is known, from the Wyanamatta beds down, is palæozoic. The curious fact of the intercalation in Australia of beds containing a mesozoic flora with marine strata abounding in carboniferous mollusca serves to show how much caution must be used in forming conclusions as to the age of beds from plant fossils alone, and this argument is especially applicable to the Damúda rocks of India, the flora of which has so remarkable a resemblance to that of the Australian beds.

Another reason for caution in coming to a conclusion from palæobotanical evidence as to the age of the Damúda beds, is to be found in the very remarkable circumstance that whereas their flora agrees best with that found in the upper palæozoic rocks of Australia, the plants found in the underlying Karharbári beds comprise more forms common to the lower triassic flora of Europe than the Damúda beds contain. A somewhat similar anomaly, although on a far smaller scale, is to be seen in the triassic deposits of Central Europe : the St. Cassian beds, containing several representatives of palæozoic generic types, are considered, by the geologists who have described them, newer than the Muschelkalk, in which no palæozoic genera occur. Such anomalies are probably due to the migration of a fauna or flora from one region to another, and to the persistence of peculiar forms in isolated regions.

Relations to Karoo series of South Africa.—Some of the peculiar genera of plant fossils of the Indian coal-fields have also been found in China on the one hand and South Africa on the other, but no detailed descriptions of the rocks in the former country have hitherto been published,[1] whilst the flora of the South African formation is but imperfectly known, and suffers from the same disadvantage as in India, the absence of marine fossils as a guide to its age. Nevertheless, the relations of the South African rocks to the Gondwána series in India are so remarkable that a brief notice of the former is necessary. The probable representation of the Tálchir boulder bed by a breccia apparently of glacial origin at the base of the Karoo beds of South Africa has already been mentioned.

[1] A full account by Baron F. von Richthofen is expected shortly.

The following is the succession[1] of lower secondary strata in Southern Africa, the lowest beds being very probably upper palæozoic:—

UITENHAGE FORMATION—Jurassic.

KAROO SERIES—

1. Stormberg beds: *Glossopteris, Dicynodon*, &c.
2. Beaufort beds: *Glossopteris browniana, G. sutherlandi, Dictyopteris? simplex, Rubidgea mackayi, Phyllotheca*, species of *Dicynodon, Oudenodon, Cynochampsa, Galesaurus*, and numerous other reptiles, a labyrinthodont amphibian, *Micropholis stowii*, and *Palæoniscus*.
3. Koonap beds.
4. Ecca beds: These include the great breccia already noticed. Some plants resembling those in the Beaufort beds are said to occur.

It will be seen that, small as the flora is, it is very similar to that of the Damúda series. One species, *Glossopteris browniana*, is identical, not only with the Indian, but with the Australian form. *G. sutherlandi* is a narrow-leaved species like the Indian and Australian *G. angustifolia* and *Dictyopteris? simplex* appears also to be a *Glossopteris* and resembles some Indian forms. *Rubidgea* is apparently very closely allied to the Damúda *Palæovittaria*. The flora consists of ferns and *Equisetaceæ*. Nor is this all. The Dicynodonts are not represented in the Damúda rocks, but two species are found in the overlying Panchets, and *Micropholis stowii* is a near ally of *Brachiops laticeps* from the Kámthi beds of Mángli.

Lastly, in the Uitenhage formation is found a flora closely resembling that of the upper Gondwána beds, and containing two species apparently identical with Rájmahál plants, and others which are nearly allied. It is a singular fact also that in several parts of Southern Africa, the next formation to the Karoo series in descending order is the almost unfossiliferous "Table Mountain sandstone," which in some respects resembles the upper Vindhyans of India. In other South African localities, however, true carboniferous deposits, with *Lepidodendron, Sigillaria*, &c., underlie the Karoo series unconformably.[2]

It thus appears that the flora of the Damúda series, so far as is at present known, is not represented in Europe by any known fossil flora, although some of the plants are allied to species found in various lower secondary formations. Floras closely agreeing with that preserved in the Damúda beds are, however, met with in Australia and South Africa. On the other hand, the plants of the Karharbári group below the Damúdas, and of the overlying Panchet beds, are much more closely allied to European forms, although several of the associated types of plants in the former, and of animals in the latter, are still

[1] Q. J. G. S., 1867, pp. 140, 167. | [2] Q. J., G. S., 1871, pp. 49, 57, &c.

more nearly allied to Australian or South African genera than to any hitherto discovered in Europe.

Barakar group.—Although there is little difference between the floras found in the various sub-divisions of the Damúda series, the characters and relations of the minor groups require separate notice, and of these groups the lowest and the most important is the Barákar. This group derives its name from a river which traverses the western portion of the Ániganj coal-field and then falls into the Damúda within the limits of the field.[1] In the higher portion of its course the Barákar river receives the streams which drain the Karharbári coal-field.

Petrology.—The Barákars have an equally extensive range with the Tálchirs, and consist of conglomerates, sandstones of various kinds, shales and coal. The sandstones are often coarse and felspathic, a variety of frequent occurrence being rather massive, white or pale brown in colour, soft at the surface where exposed, and not much harder below, consisting of grains of quartz and *decomposed* felspar. The weathered surface of this sandstone frequently exhibits small projecting knobs, due apparently to calcareous concretions. One of the most striking distinctions between the sandstones of the Tálchirs and those of the overlying formation consists in the felspathic constituents of the former being, as a rule, undecomposed, whilst in the Damúda formation the grains of felspar are almost invariably converted into kaolin.

Besides the whitish felspathic sandstone, another typical Barákar rock is a conglomerate of small, well-rounded, white quartz pebbles. These are sometimes found scattered over the surface and serve to indicate the presence of the conglomerate where it is not exposed in section. The matrix of the conglomerate is usually white sandstone.

It must not be supposed that white is the only colour of the Barákar sandstones. Brown, red, yellow, and other tints are to be found, and in many places predominate. But the whitish felspathic sandstone is a typical rock, preserving its character in localities as far apart as Rániganj in Bengal and Chánda in the Central Provinces; and although, to the eastward, it is subordinate and forms but a small portion of the group, it appears to be much more largely developed in the Godávari valley.

In general, however, to the eastward, the greater portion of the Barákar rocks consist of shales, grey, blue or black, frequently micaceous, and more or less sandy, occasionally associated with argillaceous iron ore, and often containing seams of coal. Not unfrequently the shaly beds are interstratified with hard flags.

[1] Mem. G. S. I., III, p. 212.

The coals of the Barákar group vary greatly in quality and character in the different coal-fields. They all, however, agree in having a peculiar laminated appearance, due to their being composed of alternating layers of bright and dull coal, the former purer and more bituminous than the latter, which in many cases is shale rather than coal. The best coals are those in which the bright layers predominate, but nearly all seams hitherto discovered are somewhat inferior to average European coal of the carboniferous formation, and there is a general tendency to variation in the thickness and quality of each seam within short distances. At the same time excellent fuel has been obtained from some Barákar seams. Some coal-beds are of immense thickness, single seams (including partings of shale) amounting to as much as 35 feet in the Rániganj coal-field, 50 feet near Chánda, and no less than 90 feet at Korba in Bilaspúr.[1]

Relations to Talchirs.—In places the Barákars rest quite conformably upon the Tálchirs, and the two groups appear to pass into each other. In general there is an abrupt change in mineral character, but the only case which has hitherto been found in which there is clear evidence of denudation having removed portions of the lower beds during the deposition of the higher group[2] is in the Rámgarh coal-field, where rolled fragments derived from the Tálchirs have been found in the Barákar beds. The Barákars, however, overlap the underlying Tálchirs in many places, and rest upon the metamorphic rocks, and in some coal-fields, as in Rániganj, the overlap appears to be gradual, the highest beds of the Tálchirs first disappearing, as if they had suffered from denudation. It yet remains to be seen, in the cases in which an apparent passage between the Barákar and Tálchir groups exists, whether representatives of the Karharbári beds do not intervene.

Thickness.—The Barákars appear nowhere to exceed the thickness of 3,300 feet, a development which they attain only, so far as is known, in the Jharia field. In no other field, except Rámgarh, do they exceed 2,000 feet.

There is but little difference in general between the fossil plants of the Barákars and those of the overlying sub-divisions of the Damúdas.

Ironstone shales.—Above the Barákar group in the Rániganj and a few other fields of the Damúda valley, but nowhere else, there is found a great thickness of black or grey shales,[3] with bands and nodules of clay ironstone (carbonate of iron mixed with clay), some of which is of the carbonaceous variety known as "black band." Towards the base these

[1] The most eastern district of Chhattisgarh, Central Provinces. The locality is about 235 miles east by north from Nágpúr.

[2] Mem. G. S. I., VI, p. (113).

[3] Mem. G. S. I., III, p. 40.

beds become more sandy, and interstratifications of sandstone occur amongst them. The shales disintegrate slowly, and consequently the tract covered by this group is barren and frequently elevated, but the rocks, as a rule, are not well exposed on the surface, although their presence is indicated by fragments of ironstone being scattered about.

The greatest thickness attained by the ironstone shales is about 1,500 feet in the Bokáro coal-field; in the Rániganj field they are nearly as thick. As a rule, they are quite conformable to the underlying Barákars; some slight unconformity which has been observed is very possibly local, but one case[1] has been noticed in which a break in time may be indicated.

Fossils are not common, and, when any occur, they consist usually of *Glossopteris* or *Vertebraria*. Fragments of the stem of a conifer have also been found in these beds, and somewhat resemble a form found in the Kámthi beds of Mángli.

Raniganj group.—The highest group of the Damúda series in the Damúda valley derives its name from the principal town of the mining district of Burdwan,[2] and comprises a great thickness of coarse and fine sandstones with shales and coal seams. The sandstones are, as a rule, moderately coarse, in thick massive beds, white or brown in colour, and obliquely laminated. They are usually more or less felspathic, the felspar being converted into kaolin. Bands of rather calcareous, fine, hard, yellow sandstone are common and characteristic of the group: they often weather out at the surface in nodular fragments. Conglomerates are of rare occurrence. Shales form a much smaller portion of this group than they do (in the Damúda area) of the subjacent Barákars; they are sometimes black and carbonaceous, sometimes bluish-grey, and occasionally red or brown, more or less mixed with sand or stained by iron, and small bands of argillaceous ironstone occasionally occur, though they are not common. The coal is composed of layers, alternately bright and dull, as in the Barákars.

This group is of considerable thickness in the Rániganj field, being, where fully developed, as much as 5,000 feet from top to bottom, and it is possible that this is less than the original thickness, for the next group in ascending order rests upon the denuded surface of the present. The Rániganj group diminishes in thickness in the other fields to the westward, and appears to be represented by groups of different mineral character beyond the limits of the Damúda drainage.

[1] Mem. G. S. I., III, p. 42.

[2] Mem. G. S. I., III, p. 46.

As a general rule, the Ránigan j beds are conformable to the ironstone shales, but in the Bokáro coal-field, near Hazáribágh,[1] the higher group overlaps the lower unconformably and rests upon the Barákars.

No animal remains have been found in the rocks of this formation, but plants are abundant; the majority appear to be the same as those found in the Barákars.

Motur group.—This and the next sub-division are only known to occur in the Sátpúra ranges south of the Narbada valley, where the groups immediately succeeding the Barákars in ascending order have not received the same amount of attention as the rocks of Bengal, the Godávari valley, and Orissa, and the classification proposed for the Sátpúra Gondwánas is only provisional. An immense thickness of beds occurs, probably as much as in the Ránigan j field, but no correct estimate can be formed without further detail.

The Motúr group[2] derives its name from a village of that name situated about twelve miles south-south-east of Pachmari, on the dividing ridge between the valleys of the Denwa (which runs into the Tawa, a tributary of the Narbada) and the Pench (which is a tributary of the Godávari). The village is on the road from Badnúr (Betúl) and Chhindwára to Pachmari, and was at one time used as a sanatarium.

The beds of this group somewhat resemble the Panchets of Bengal in mineral character. They consist of thick, coarse, soft, earthy sandstones, grey and brown, sometimes with red and mottled clays and calcareous nodules. Shales occur, but they are usually sandy and very rarely carbonaceous.

It is probable that the Motúr group is unconformable to the Barákars. No collections of fossils have hitherto been made from the beds of the Motúr horizon.

Bijori group.—The highest members of the Damúda series in the Sátpúra region are exposed in the upper Denwa valley at the southern base of the Mahádeva or Pachmari hills. For the rocks of this horizon the name of Bijori has been proposed,[3] from a small village rendered famous by being the locality whence the only distinctly vertebrate fossil, except *Brachyops*, yet obtained from the Damúda series has been procured.

The rocks of the Bijori horizon are characteristically Damúdas, and comprise shales, occasionally carbonaceous, micaceous flags and sandstones.

Of the relations between the Bijori and Motúr groups nothing definite is known, nor has the thickness of either been determined; 3,000

[1] Mem. G. S. I., VI, p. (100).
[2] Mem. G. S. I., X, p. (131).
[3] Mem. G. S. I., X, p. (129).

to 4,000 feet of beds intervene between the Motúr beds and the base of the Pachmari sandstone, and the greater portion of this thickness may be assigned to the Bijori group.

The most important fossil hitherto found in the Bijori beds is the specimen already referred to, which is the skeleton of an amphibian apparently allied to, if not congeneric with *Archegosaurus*, a carboniferous genus.[1] Plants of the ordinary Damúda types, *Glossopteris*, *Vertebraria*, &c., are found, and *Schizoneura* has also been met with.

Kamthi and Hengir.—Although there is some difference in mineral character between these two groups, the latter, in Chhattisgarh and Western Orissa, appears so closely to represent the beds of the Godávari valley that the two may be united. The name Kámthi is derived from the military station so called,[2] twelve miles north-east of Nágpúr, and the station again derives its name from a village on the opposite side of the Kanhán river, where there is a famous quarry which has yielded a large number of fossils. The term Hengir is derived from a zamindári of that name situated north of Sambalpúr.[3]

The typical Kámthi rocks consist of conglomerates, grits, sandstones, shales and clays. The conglomerates contain pebbles of quartz; the grits are sometimes hard and silicious, so much so as to be quarried for hand-mills (quernstones), but usually they are soft and argillaceous. They are frequently stained by iron, and are often intersected by hard ferruginous bands of a dark-brown colour. The sandstones are of every shade of colour, and vary greatly in character; they comprise fine-grained micaceous beds, white in colour, with blotches and irregular streaks of red, and one of the most characteristic beds of the formation is a very fine argillaceous sandstone, hard, massive, and homogeneous, resembling a shale in structure, except that it exhibits no trace of lamination, yellow in colour below the surface, but becoming red when exposed. It passes into red shale. Another characteristic bed is a hard grey grit or sandstone ringing under the hammer and breaking with a conchoidal fracture. The clays are red or green in colour, and chiefly prevail in the upper portions of the group.

These typical beds, with the exception of the clays, are chiefly developed near Nágpúr; elsewhere the Kámthis consist mainly of soft porous sandstone, brown or white in colour, and conglomeratic in places, often with hard, ferruginous bands, and a few red shales. Here and there, however,

[1] J. A. S. B., XXXIII, 1864, pp. 336, 442.

[2] Rec. G. S. I., 1871, IV, p. 50; Mem. G. S. I., IX, p. (305). The name was formerly written Camptee, and this subsequently assumed the form of Kampti.

[3] Rec. G. S. I., 1875, VIII, p. 112.

a band of one of the characteristic rocks is met with towards the base of the formation.

The chief peculiarity which distinguishes the Kámthi group from the Rániganj and Bijori groups is the absence of carbonaceous markings. In other Damúda groups, with the exception of the ironstone shales, the remains of plants retain in general a portion of their original carbon, but this appears very rarely to be the case amongst the Kámthis.

The thickness of the Kámthi group has not been determined, but it is undoubtedly considerable, probably 5,000 to 6,000 feet at least.[1] The beds belonging to this group generally appear conformable to the Barákars, but it is extremely doubtful if the conformity be more than apparent, for the Kámthi beds overlap the Barákars in a most irregular manner, and the break in conformity between the two is in places well marked. The Hengir beds, both near Sambalpúr and in the Tálchir coal-field, certainly rest unconformably in places on the Barákar group.[2]

Mangli beds and their fossils.—In the neighbourhood of Mángli,[3] a small deserted village, lying at the northern extremity of the Wardha Gondwána basin, about fifty miles south of Nágpúr and thirty-five north-west of Chánda, some quarries have long existed, from which a very fine red and yellow sandstone, apparently argillaceous, is obtained and employed in building, chiefly for ornamental purposes and for carvings. The stone is precisely similar to that of Silewáda and other typical exposures of the Kámthi group, near Nágpúr, and the coarser associated sandstones of Mángli differ in no way from the ordinary Kámthi grits.

The quarries of Mángli have become well known by name to Indian geologists, and even to those of other countries, from having furnished to Mr. Hislop the first Labyrinthodont amphibian fossil detected in India. They have also yielded a species of *Estheria* and a few plant-remains. The latter are so poor that very little dependance can be placed upon their determination; one is believed to be coniferous, and has been referred to *Palissya*;[4] another is a stem of a fern.

The species of *Estheria* has been named *E. mangaliensis* by Professor Rupert Jones; it is an ally of the European *Estheria minuta*, which is

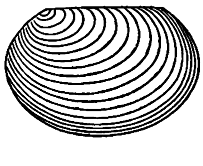
[1] The statement printed in the Rec. G. S. I., X, p. 28, that the Kámthi rocks near Sironcha are 17,000 feet thick, has since been ascertained to be erroneous, the beds being repeated by a fault.

[2] Mem. G. S. I., Vol. I, p. 65; Rec. G. S. I., VIII, p. 113.

[3] This spelling is quite as correct as Mángali, and the latter form is objectionable, since the name has, in consequence, been called and printed Mángáli or even Mangáli. The Mángli beds were discovered by the late Mr. Hislop, Q. J. G. S., XI, pp. 3780.

[4] Feistmantel, Rec. G. S. I., X, p. 26. The identification seems doubtful, for Sir Charles Bunbury suggested the possibility of the same stem belonging to the Lycopodiaceous genus *Knorria*.

a characteristic fossil of the Trias. At the same time *E. mangaliensis* closely resembles a recent species, *E. gihoni*, living in Palestine.[1]



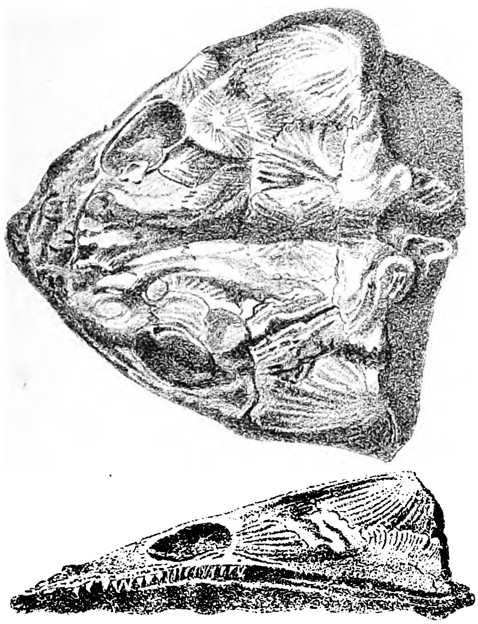
Estheria mangaliensis (enlarged 3 diameters).

The smaller variety of *E. mangaliensis* closely resembles one found in the Panchet group of Bengal, and may be identical; but the Panchet fossil is so poorly preserved that some of the specific characters, depending upon the microscopical texture of the shell, cannot be ascertained, so the identification is not quite certain. The Kámthi plant fossils consist of several forms of *Glossopteris, Gangamopteris, Tæniopteris, Alethopteris*, equisetaceous stems and leaves (*Phyllotheca, Vertebraria,* and *Schizoneura*). None of the Panchet plants except *Schizoneura* have hitherto been detected in the Kámthis. On the evidence of the plants the Kámthi beds have been referred to the Damúda series, and considered equivalent to the Rániganj group. It may, however, be mentioned that all the plants obtained hitherto from the Kámthis are from beds near the base of the group, and some of the upper Kámthi strata may yet be found to represent the Panchets of Bengal. The fossils of the Mángli beds may perhaps indicate that the whole Kámthi group should be referred to a somewhat higher horizon than the Rániganj group. This appears more probable than the idea that the Mángli beds themselves are of later date than the other Kámthi strata, a view held by some palæontologists, but which has been disproved by the geological examination of the country.[2]

[1] Rupert Jones, Pal. Soc., Mon. Foss. Estheriæ, p. 78. The specimens found at Mángli vary in size, and the smaller form is referred by Dr. Feistmantel (Rec. G. S. I., X, p. 26) to *E. minuta*, var. *brodiei*, a rhætic variety of the triassic species. It seems, however, by Professor Rupert Jones to have been described and figured as a small variety of *E. mangaliensis*.—(Q. J. G. S., 1863, p. 149.)

[2] Dr. Feistmantel considers (Rec. G. S. I., X, p. 27) that the fauna and flora of the Mángli beds are newer than those of the Panchets. His principal reason for this view appears to be the discovery by Professor Geinitz of *Estheria mangaliensis*, associated with a rhætic flora, in South America, and a supposed identification of the smaller Mángli *Estheria* with *E. minuta*, var. *brodiei*. The latter identification is apparently a mistake, as already mentioned in a previous note, and the evidence of age, afforded by terrestrial plants and animals in distant regions, is shewn by the Gondwána flora to be not unfrequently conflicting. The evidence afforded by the Mángli plants is of very little value; they are insufficient for accurate determination. At Kawársa, west of Chánda, in beds clearly and unmistakably belonging to the Kámthi group, the same *Estheria mangaliensis* occurs with *Glossopteris browniana, G. indica, Phyllotheca indica,* and *Schizoneura*, the typical Damúda fossils (Mem. G. S. I., XIII, pp. 70, 77), and this occurrence within about 30 miles of Mángli is much more important than the position of the species in South America. The palæontological evidence is thus insufficient to justify the transfer of the Mángli beds to a higher horizon, whilst the geological determination of the position of these beds, which have been carefully

The last, but by far the most important Mángli fossil, is the Labyrinthodont *Brachyops laticeps.*[1] The only allied form found in Europe is *Rhinosaurus jasikovii* from the Russian oolite. Two species belonging to the same group have been described by Professor Huxley,[2] one under the name of *Micropholis stowii* from the Beaufort group of the Karoo series in South Africa, and the other, called *Bothriceps australis,* from an unknown locality in Australia; of these different forms *Micropholis* approaches most nearly in all characters to the Mángli Labyrinthodont.



Head of *Brachyops laticeps*, upper and side views, half natural size.

Panchet group.—The term Panchet was originally applied to two groups of beds in the Rániganj coal-field.[3] It is now restricted to the lower of these groups, the upper Panchets of the Damúda valley being referred to the upper Gondwána series and ascribed to the Mahádeva formation. The name was derived from an important zamindári (estate) which still comprises a large tract in the southern portion of the Rániganj coal-field, and formerly included much more; and the same name is that of a large hill, the basal portion of which consists entirely of Panchet beds.

examined, leaves no reasonable doubt that they belong to the Kámthi group. Mr. Hughes (Mem. G. S. I., XIII, p. 71) considers that the position of the Mángli fossiliferous bed is about 600 or 700 feet above the base of the Kámthis, and that the Kawársa beds, which are of similar mineral character, are on nearly the same horizon (*ib.*, p. 75).

[1] Owen, Q. J. G. S., 1855, p. 37.

[2] Q. J. G. S., 1859, p. 642; Rept. Brit. Assoc. 1874, p. 161.

[3] Mem. G. S. I., III, pp. 30, 126, 132, &c.

Petrology.—The great mass of this group consists of thick beds of coarse felspathic and micaceous sandstones, often of a white or greenish-white colour, with bands of red clay from a few inches to 20 feet in thickness. The felspar in the sandstones is occasionally undecomposed, which is never the case in the Damúdas. Conglomeratic beds sometimes occur in the upper portion of the group, but they are not common.

At the base of the group grey and greenish-grey sandstones and shales are usually found in very thin beds, and often highly micaceous. In places the greenish micaceous clays are met with higher in the group.

The Panchet rocks are distinguished from the typical Damúdas by the presence of red clay and the absence of carbonaceous shales, and, as a rule, by the sandstone being much more micaceous. But, as already shewn in the case of the Motúr group, rocks of the Panchet character are found in parts of India interstratified with the Damúdas.

The thickness of the present group in the Damúda valley nowhere exceeds about 1,800 feet. It rests with slight but distinct unconformity upon the denuded surface of the Rániganj group, the unconformity being most marked in the Bokáro coal-field, and in some places the Panchets completely overlap that group, and rest upon lower helds. Fragments of coal and shale, apparently derived from the Damúdas, have occasionally been found in the conglomerates of the Panchet group.

Palæontology.—The most important remains of animals hitherto found in the lower Gondwána rocks have been derived from the Panchets. In the upper portion of the group there is, in the Rániganj coal-field, a well-marked conglomeratic band containing reptilian and amphibian bones. These are isolated from each other and sometimes sligbtly rolled. The specimens obtained have been examined and described by Prof. Huxley [1] and comprise the following forms, besides a few others the affinities of which are doubtful:—

AMPHIBIA—
- Labyrinthodontia—
  - *Gonioglyptus longirostris.*
  - *Pachygonia incurvata.*

REPTILIA—
- Dicynodontia—
  - *Dicynodon orientalis.*
- Dinosauria—
  - *Ancistrodon indicus.*

CRUSTACEA—
- *Estheria mangaliensis?*

[1] Pal. Ind. Ser. IV, 1.

The plants hitherto discovered consist of the following species[1] :—

EQUISETACEÆ—

Schizoneura gondwanensis. Pl. VII, fig. 1, 2, 3.

FILICES—

Pecopteris concinna. Pl. VII, fig. 6.
Cyclopteris pachyrhachis. Pl. VII, fig. 5.
Taeniopteris (*Oleandridium*) sp. allied to *O. stenoneuron.* Pl. VII, fig. 4.
Glossopteris, sp. fragments.

Prof. Huxley has pointed out that the reptilian and amphibian remains might be either older mesozoic or upper palæozoic. He says:[2] "So far as an accumulation of uncertainties may go towards forming a conviction, however, I should incline, in view of the whole vertebrate evidence (to which I confine myself) to the opinion that the Indian (*i. e.*, Panchet) fossils are either of triassic age or belong to that fauna which will one day be discovered to fill up the apparent break between the palæozoic and mesozoic forms of life."[3]

Of the plant remains *Pecopteris concinna* and *Cyclopteris pachyrhachis* are known from the rhætic of Europe, and the *Tæniopteris* also is allied to a rhætic species. The genus *Schizoneura* is found in both rhætic and trias; *S. paradoxa,* the form most nearly allied to *S. gondwanensis,* being a characteristic lower triassic fossil (Bunter). The Panchet species is considered by Dr. Feistmantel the same as that found in the beds of the Damúda series, especially in the Ràniganj, Bijori, and Kámthi groups.

Pachygonia and *Gonioglyptus* belong to the same section of the *Labyrinthodonts*[4] as *Mastodonsaurus* (trias and rhætic), *Capitosaurus* (trias), and *Trematosaurus* (trias). *Dicynodon* has not been found in Europe, but it abounds in the Beaufort beds, belonging to the Karoo series in Southern Africa, together with the plants already noticed in connection with the Damúda flora. Some of the other reptiles of the Beaufort beds are considered by Prof. Owen to be allied to permian forms, but the rocks have been by other observers either classed as trias or considered as belonging to a period comprising permian and trias, and corresponding to the old "Poikilitic." The balance of evidence, perhaps, is in favour of a triassic age both for the Panchet group of India and the Beaufort beds of South Africa.[5]

[1] Rec. G. S. I., IX, p. 65.

[2] *L. c.*, p. 24.

[3] Subsequently (Q. J. G. S., XXVI, 1870, p. 49) Prof. Huxley expressed an opinion that the Panchets, together with several other reptilian faunas in Europe, Asia, and Africa, were more probably triassic than permian. The definite classification of the Indian beds has, however, been seriously impeded by the discovery that the Maleri *Reptilia*, which have much stronger triassic affinities than the Panchet forms, and which were formerly supposed to occur on the same horizon, belong to much higher beds.

[4] Rept. Brit. Assoc., 1874, pp. 150, 155, 156.

[5] Q. J. G. S., 1867, p. 167; 1870, p. 49; 1876, p. 352.

Almod.—This name is derived from a village at the south base of the Pachmari escarpment in the Sátpúra hills. The rocks consist of sandstones with a few carbonaceous shales. Their relations to the groups above and below require further investigation; no unconformity has hitherto been traced. Their sole importance is derived from their position between the Mahádevas and Damúdas, and to the suggestion that they may represent the Panchet group of Bengal. No fossils have, however, as yet been found in them.

CHAPTER VI.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued.*

Upper Gondwána groups—Mahádeva Series—Pachmarhi group—Denwa group—Bágra group—Dubrájpúr group—Rájmahál group—Characters and association of bedded traps—Rájmahál beds in Southern India—Thickness and relations to lower Gondwánas—Area of volcanic action—Palæontology—Relations to Uitenhage flora of South Africa—Relations to Jabalpur and Cutch floras—Ragavapuram shales—Tripetty sandstones—Sripermatur group—Sattavedu group—Trichinopoly or Utatur plant beds—Kota-Maleri group—Palæontology—Jabalpur group—Palæontology—Umia group of Cutch—Narha beds.

Upper Gondwana groups.—The area in which the upper portion of the Gondwána system appears most fully represented, is the Sátpúra basin; and here, although there is evidence of a marked break in the sequence, the division between the upper and lower sub-divisions of the great system is less trenchant than in Bengal. So far as the examination of the Gondwána formations has hitherto proceeded, there appears to be but little connexion between the floras of the upper and lower series, and it is quite possible that several intermediate links remain to be discovered between the Panchet group and the next fossiliferous formation in ascending order, that of Rájmahál. It has already been noticed that the upper Gondwána formations, in each tract in which they occur, differ more from the corresponding rocks in other tracts than the lower Gondwána groups do, and consequently the correlation of the different members of the series is more difficult, and a larger number of small local groups has been instituted. In treating of the upper Gondwána formations, the groups of the Mahádeva series will be first mentioned, then the Rájmahāls and their equivalents; next, the minor groups of the east coast; and, finally, the Kota-Maleri, Jabalpur, and Cutch beds. The general relations between the various groups have already been represented, so far as is practicable, in the table given in the last chapter.

Mahadeva series.—This name was first applied to the sandstone of the Pachmarhi hills,[1] a part of the Sátpúra range south of the Narbada,

[1] J. A. S. B., 1856, XXV, p. 252; Mem. G. S. I., II, pp. 183, 315.

between Hoshangabád and Narsingpúr; these hills are known as Mahádeva or Mahádeo from a cave sacred to Siva, which is the site of a great annual "mêla," or pilgrim fair, in honour of the god. Subsequently the term was extended so as to comprise all the upper beds of the Sátpúra basin, above the Damúdas of the upper Denwa valley, except the Jabalpurs.

The Mahádeva rocks consist chiefly of very thick massive beds of coarse sandstone, grit, and conglomerate. These are frequently ferruginous, or marked with ferruginous bands, as in the Kámthis. They are associated with clays, and occasionally with bands of impure earthy limestone. The sandstones form high ranges of hills, and often weather into vertical scarps of great height, forming conspicuous cliffs in the forest, and contrasting strongly with the black precipices of the Deccan traps and the rounded irregular masses of the more granitoid metamorphic rocks.

In the typical area of the Sátpúra region the Mahádeva rocks attain a thickness of at least 10,000 feet, nine-tenths of which consist of coarse sandstone, grit, and conglomerate. The formation, as a whole, appears to be unconformable to the underlying Damúdas, as it overlaps the upper members of the lower Gondwána series.

Unfortunately the whole of this immense thickness of beds has hitherto yielded scarcely any recognisable fossils. Fragments of wood apparently exogenous, and imperfect remains of stems and leaves, have occasionally been met with, but never hitherto in a state which permitted their characters to be determined.[1] Quite recently a scute of an amphicœlian crocodile has been found in the Denwa valley, and some leaves of *Ptilophyllum* at Lokartalai. The latter are of great importance, but they belong to forms having a wide range in the upper Gondwána strata.

The Mahádeva formation has recently been sub-divided in the Sátpúra region into three groups, the Bágra, Denwa, and Pachmarhi, each of which requires a few remarks.

Pachmarhi group.—The name is derived from Pachmarhi,[2] a village on the top of the hills of the same name, and the site of a sanitarium. The group consists of massive sandstone, whitish or brownish in colour, usually soft, often containing small subangular pebbles, and occasionally intersected by hard ferruginous bands. As a rule, the stratification is

[1] The fossil wood mentioned in the report on the central portion of the Narbada district (Mem. G. S. I., II, p. 190) occurs in beds which have now been shewn to belong to the Jabalpur group and not to the Mahádevas.

[2] Mem. G. S. I., X, p. (155).

obscure, oblique lamination being common, and the different beds of which the group is composed exhibiting great irregularity in superposition and often overlapping each other. The hard ferruginous partings are most irregularly interspersed throughout the mass, usually as thin beds, though not always perfectly parallel to the planes of stratification; sometimes the impregnation with iron is confined to pipes or nodules. Fragments of these ferruginous bands are often scattered in quantities over the surface, and serve to distinguish the outcrop of the Pachmarhi group from those of the underlying beds.[1]

The Pachmarhi group comprises, where thickest, 8,000 feet out of the 10,000 found in the Mahádevas of the Sátpúra hills.

Denwa group.—The middle group of the Sátpúra Mahádevas is named[2] after a stream which rises on the south side of the Pachmarhi range, and turning round the eastern end of the ridge, forms its northern boundary throughout and finally falls into the Tawa. The course of this stream, north of the Pachmarhi hills, is the area of the Denwa rocks, which present a marked contrast to the massive Pachmarhi sandstone, and are principally composed of soft clays, pale greenish-yellow and bright-red mottled with white in colour, forming thick beds interstratified with discontinuous and subordinate bands of white sandstone, and very rare courses of earthy limestone. The sandstones are locally conglomeratic. In short, in mineral character, the Denwa rocks are a repetition of the Motúr group in the middle of the Damúda formation, and resemble the Panchets of Bengal.

The thickness of these beds in the Denwa valley is about 1,200 feet. They appear in places to pass into the underlying group, although in the typical area they are quite distinct.

A fossil reptilian scute, found in the Denwa rocks[3] by Mr. Hughes, appears to have belonged to a crocodile with bi-concave vertebræ, like *Belodon* and *Parasuchus*. The scute in question is very large, and may perhaps have belonged to the last-named genus, which is found in the Kota-Maleri beds. The occurrence is scarcely sufficient to afford much aid in determining the homotaxis of the Denwa beds, but it is interesting, as possibly shewing some connection with the Kota-Maleri group.

At Lokartalai, on the Moran river, close to the western extremity of the Sátpúra basin, some shales and sandstones, having a decidedly Damúda aspect, crop out in an anticlinal from beneath the overlying Bágra beds. These beds even comprise a seam of inferior shaly coal. In mineral

[1] It should not be forgotten that similar ferruginous layers are found in the Kámthis, belonging to the Damúda series.

[2] Mem. G. S. I., X, page (153).

[3] Lydekker, Rec. G. S. I., X, p. 34.

character they closely resemble the Bijori sub-division of the Damúdas, and, until recently, they were classed as lower Gondwánas. Mr. Hughes, however, has now found the two characteristic species of *Ptilophyllum*, *Pt. cutchense* and *Pt. acutifolium*, in these beds, and there can be no hesitation in referring them to the upper Gondwána series : they probably belong to the Denwa group. As the two plants named are found in both the Rájmahál and Cutch groups, the correlation is still imperfect, but the Denwa beds cannot be of much later age than the Rájmaháls, as they are separated from the Jabalpur group, itself, if anything, a little anterior in date to the Cutch beds, by the Bágra sub-division of the Mahádevas.

Bagra group.—This name is that of a hill fort[1] built upon the highest sub-division of the Mahádeva formation at the spot where the river Tawa cuts its way through a spur of the Sátpúra hills, south-east of Hoshangabád.

The Bágra group is very largely composed of conglomerate, often coarse, and frequently with a deep red, earthy and sandy matrix. It is more calcareous than any of the other Mahádeva groups, and bands of limestone, sometimes dolomitic, and of calcareous sands and clays, are of frequent occurrence. The limestones are pink or yellowish, whilst clays and sandstones of various colours are interstratified with the conglomerates and limestones. The group is very irregular in composition. The greatest thickness hitherto observed does not exceed 600 to 800 feet. In places the Bágra beds overlap the Denwa group, and rest on the Pachmarhi sandstones.

Dubrajpur group.—The three groups already noticed are only known in the Sátpúra region, although some of them may perhaps hereafter be traced to the eastward. Owing to the paucity of fossil evidence in the Mahádeva series, and to the great difference in mineral character between the upper Gondwána beds of the Central Provinces and those of Bengal, it is impossible to say which groups in the former area are represented in the latter, where the most important group by far is that of Rájmahál.

A thick band of coarse sandstone at the base of the Rájmahál group was at first associated with the overlying beds, but it has since been separated, as it is not conformable to the Rájmaháls, and as it is very similar in character to some sandstones of the Damúda valley, formerly described as upper Panchets, but since believed, on evidence which will be noticed in a subsequent chapter relating to the coal-fields of the Damúda valley, to be a probable representative of the lower Mahádevas.

[1] Mem. G. S. I., X, p. (150).

The Dubrájpur group, as this band of sandstones and conglomerates is called, takes its name from a village [1] in the Rájmahál hills, situated about 40 miles north by east of Soory (Suri). The component beds are sandstones of several varieties (grits and conglomerates), for the most part ferruginous. Fine-grained beds are not common, although occasionally shaly sandstones are met with. Most of the coarser beds are ferruginous, and one form of conglomerate, of frequent occurrence, consists of quartz pebbles in a ferruginous matrix. A precisely similar bed is found in the supposed Mahádeva beds of the Damúda valley.

Along the western scarp of the Rájmahál hills, the rocks of the Dubrájpur group rest partly upon the Damúdas and partly upon the metamorphic rocks, the Damúdas (Barákars) being repeatedly overlapped by the Dubrájpur beds in a manner which shews the two to be quite unconformable. The greatest thickness of the Dubrájpur group in the Rájmahál area does not exceed about 450 feet. Some specimens of a cycadaceous plant (*Ptilophyllum*) were once found in the uppermost beds underlying the Rájmahál trap near the southern extremity of the hills; but there is some little doubt as to whether the fossiliferous band may not belong to the Rájmáhal group itself.

Rajmahal group.—This important group derives its name from a range of hills in Bengal,[2] extending north and south from the Ganges to the neighbourhood of Soory (Suri) in Birbhúm. The range again is named from the town of Rájmahál on the Ganges at the northern end of the hills. The representatives of the Rájmahál group, unlike those of other members of the Gondwána series, are confined to the neighbourhood of the eastern coast of the Indian Peninsula. Some species of fossil plants, identical with Rájmahál forms, have been found in other localities, but they are either isolated or associated with plants belonging to a different flora.

Characters and association of bedded traps.—In its typical locality the Rájmahál group consists of a succession of basaltic lava-flows or traps with interstratifications of shale and sandstone. The sedimentary bands are proved to have been deposited in the intervals of time which elapsed between the volcanic outbursts, by the circumstance that the different bands of shale and sandstone differ from each other in mineral character, and also that the upper surface of the shaly beds has sometimes been hardened and altered by the contact of the overlying basalt, whilst the

[1] Pal. Ind., Ser. II, p. 1; Mem. G. S. I., XIII, p. (198).

[2] J. A. S. B., 1854, XXIII, p. 270; Mem. G. S. I., II, p. 313; XIII, p. (209); Pal. Ind., Ser. II, p. 1.

lower surface is never affected. The sedimentary bands are chiefly composed of hard white and grey shale, carbonaceous shale, white and grey sandstone, and hard quartzose grit.

Rajmahal beds in Southern India.—The representatives of the Rájmahál group in other parts of India only comprise volcanic rocks in one locality, on the southern face of the Khási hills overlooking Sylhet in north-eastern Bengal, and in this instance the identification is not perfect, as it depends upon mineral character. There are no sedimentary intertrappean beds, and no fossils have been found. Near the eastern coast, however, representatives of the Rájmahál group have been recognised by their fossil plants in several localities. These representative beds consist of coarse sandstones, often conglomeratic; clays and shales, many of the latter being white and hard, and somewhat resembling the typical intertrappean beds of the Rájmahál area. The sandstones are sometimes richly coloured, red or yellow, but more often grey, white or brown, and they are usually soft and argillaceous. Towards the base of the group a very coarse conglomerate is found, often containing immense blocks of gneiss or other crystalline rocks derived from the immediate neighbourhood.

Such is the general character of the beds; it should, however, be added that there is much variation in the rocks found at the various outcrops which are scattered along the coast at intervals from Cuttack to Trichinopoly, and that, in several cases, distinct zones can be traced, which appear to be of rather later date than the Rájmaháls. Some details of the different outcrops will be given in a subsequent chapter; for the present it is sufficient to point out that the beds of Atgarh near Cuttack[1] and those of Golapilli[2] near Ellore, have the same flora as the Rájmahál group of Bengal; that above the Golapilli beds there are two minor groups, the Ragavapuram shales and the Tripetty sandstones; that these, rather than the true Rájmahál beds, may perhaps be the equivalents of the Sripermatúr and Sattavedu groups near Madras; and that the Trichinopoly or Utatúr plant beds, the flora of which is imperfectly known,[3] may perhaps, like the Sripermatúr beds, be a little higher in position than the Rájmahál group proper. Some beds near Ongole are composed of white hard shales similar to the Ragavapuram beds. The general relations of these

[1] Ball, Rec. G. S. I., X, p. 63; Feistmantel, ib., p. 68.

[2] King, Rec. G. S. I., VII, p. 159; X, p. 56: Feistmantel, Rec. G. S. I., IX, p. 40; Pal. Ind., Ser. II, pt. 3.

[3] Whilst these pages are passing through the press, news has been received of an important discovery of plants in these beds by Mr. Foote.

different minor groups, so far as they have hitherto been determined, is shewn in the following table[1]:—

Bengal.	Orissa.	Ellore.	Ongole.	Near Madras.	Trichinopoly.	Central Provinces.	Cutch.
———	———	Tripetty and Innaparazpolliam.	Sandstones near Guntoor.	———	———	? Chikiala.	Umia.
———	———	———	———	? Sattavedu.	———	Jabalpur	Katrol.
———	———	Ragavapuram.	Plant beds.	Sripermatúr.	Utatúr plant beds.	———	? Chari.
Rájmahál.	Atgarh.	Golapilli.	Sandstones of Budhanada.	———	———	———	———

It should, however, be understood that the distinctions between the groups are not great, and that in several cases the fossil flora has hitherto only been imperfectly examined. A few remarks on the Ragavapuram, Tripetty, Sripermatúr, and Sattavedu sub-divisions will be added after a description of the physical relations and palæontology of the Rájmahál group, as restricted to the beds of Bengal, Orissa, and Ellore.

Thickness and relations to lower Gondwanas.—The bedded basaltic traps of the Rájmahál hills with their associated sedimentary beds attain a thickness of at least 2,000 feet, of which the non-volcanic portion never exceeds in the aggregate 100 feet. The thickness of the beds in Southern India has never been determined. The traps in the typical area rest with general parallelism on the grits and coarse sandstone of the Dubrájpur group, but nevertheless several instances of overlap take place, and in one locality at least there is evidence of the Dubrájpur beds having been denuded before the deposition of the Rájmahál group. In Southern India the Rájmahál beds have been deposited on metamorphic rocks, and appear in general to rest upon a sloping surface, dipping towards the present sea-coast, and having the appearance of an ancient plane of marine denudation.

The great difference of age between the Rájmahál group on the one hand and all the lower Gondwána rocks, including the Damúdas

[1] This differs slightly from several tables by Dr. Feistmantel (*e. g.*, Pal. Ind., Ser. II, 3, p. 165), who unites the Umia and Katrol groups of Cutch. As, however, only two species of Cephalopoda are known to be common to the two groups, although eleven species are found in the Umia, and no less than twenty-seven in the Katrol beds, it is impossible to consider these groups as identical because a few plants are common to both: see the chapter on the Jurassic series.

and Panchets, on the other, is well illustrated by the change in the flora and by the very much greater amount of disturbance to which the Damúda rocks have been subjected. The Rájmahál traps are almost horizontal, and no faults have been observed in them. As will be shewn in the account of the Rániganj field, the dykes which abound there are almost certainly of Rájmahál age, and they are newer than the faults of the coal-field.

Area of volcanic action.—From the extent of the area throughout which these dykes are developed, conclusions may be drawn as to the original limits of the volcanic action coincident with the period of deposition of the Rájmahál group. The number of trap dykes gradually diminishes in the coal-fields of the Damúda valley from east to west, until finally in the Karanpura field, south-west of Hazaribágh, volcanic intrusions disappear almost entirely, and none appear to be known further west until basaltic dykes of different age, which apparently are of contemporaneous origin with the much newer Deccan trap (upper cretaceous) make their appearance. Outside of the coal-fields it is difficult to distinguish the dykes belonging to the Rájmahál period from older eruptions, but there is not in Southern Monghyr, Hazaribágh, and Chutia Nágpúr the same abundance of extensive basaltic intrusions as in Birbhúm. So far as can be judged, the region immediately north of the Rániganj coal-field was one of the foci of eruption, and it is far from improbable that the bedded traps of the Rájmahál hills had originally a considerable extension to the south-west and south, though, as no single outlier has been preserved, it is impossible to feel sure of the inference. There is, however, considerable probability that a large tract in the Damúda valley, including the whole Rániganj field, may have been once covered with bedded traps.

Palæontology.—The following[1] is a list of the fossil plants hitherto described from this group, including the species found in the Rájmahál

[1] Pal. Ind. Ser. II, Rec. G. S. I., IX, p. 34. On Plates VIII and IX of the present work the following Rájmahál plants are figured:—

Plate VIII, fig. 1.—*Ptilophyllum acutifolium.*
" " 2.—*Pterophyllum rajmahalense.*
" " 3.—*P. princeps.*
" " 4.—*Cycadites confertus.*
" " 5.—*Otozamites bengalensis.*
" " 6.—*Dictyozamites falcatus.*
" " 7.—*Palissya conferta.*
Plate IX, fig. 1.—1*a*.—*Gleichenia bindrabunensis.*
" " 2.—*Alethopteris indica.*
" " 3.—*Pecopteris lobata.*
" " 4.—*Tæniopteris spathulata.*
" " 5.—*T.* (*Macrotæniopteris*) *lata.*

hills, and also those from Atgarh and Golapilli. The names in brackets are those by which the species were originally described by Oldham and Morris :—

EQUISETACEÆ—

Equisetum rajmahalense (*Equisetites rajmahalensis*).

FILICES—

Sphenopteris (*Eremopteris*) *hislopi*.
S. (*E.*) *membranosa*.
S. (*Davallioides*) *arguta*.
S. (*Dicksonia*) *bindrabunensis*.
S. (*Hymenophyllites*) *bunburyana*.
Cyclopteris oldhami.
Thinnfeldia salicifolia (*T. indica*, Fstm., *Pecopteris salicifolia*, O. and M.).
Gleichenia bindrabunensis (*Pecopteris* (*Gleichenites*) *gleichenoides*).
Alethopteris indica (*Pecopteris indica*).
Asplenites macrocarpus (*Pecopteris macrocarpa*).
Pecopteris lobata.
Tæniopteris (*Macrotæniopteris*) *ovata* (*T. ovalis*, O. and M. nec. L. and H.).
T. (*M.*) *lata*.
T. (*M.*) *crassinervis*.
T. (*M.*) *morrisi*.
T. (*Angiopteridium*) *macclellandi* (*Stangerites macclellandi*).
T. (*A.*) *spathulata* (*Stangerites spathulata*).
T. (*A.*) *ensis* (*Stangerites ensis*).
Danæopsis rajmahalensis.
Rhizomopteris balli.

CYCADEACEÆ—

Pterophyllum distans.
P. carterianum.
P. crassum.
P. rajmahalense.
P. propinquum ?
P. morrisianum.
P. medlicottianum.
P. princeps.
P. fissum.
Ptilophyllum acutifolium.
P. cutchense.
Otozamites bengalensis (*Palæozamia bengalensis*, O. & M.; *Otozamites abbreviatus*, Fstm.).
O. near *O. brevifolia* (*O. bengalensis*, Schimper).
O. oldhami (*Palæozamia bengalensis var. obtusa*).
Zamites proximus.
Dictyozamites falcatus (*D. indicus*, Fstm.; *Dictyopteris falcata*, O. & M.).
Cycadites rajmahalensis.
C. confertus.
Williamsonia near *W. gigas*.

W. microps.
Cycadinocarpus rajmahalensis.

CONIFERÆ—
Palissya indica (*Taxodites indicus*).
P. conferta (*Cunninghamites confertus*).
Cunninghamites dubiosus (*C. inæquifolius*, O. and M.).
Chirolepis gracilis (*Araucarites gracilis*).
C. sp. near *C. muensteri.*
Araucarites macropterus.
Echinostrobus indicus (*E. rajmahalensis*,[1] Fstm., *Arthrotaxites indicus*, O. and M.).

By far the greater part of the Rájmahál fossils have been obtained from two bands of fine-grained whitish or greyish shales—the upper 25 to 30 feet thick, the lower 10 to 15—separated from each other by a lava flow, and having other beds of trap with intercalations of sandstone and shale above and below.

The first thing which must strike any one in looking over the above list is the great change in forms of life between the upper and lower Gondwána series, so far as we are yet acquainted with them. It is highly probable that intermediate beds may hereafter be found, but for the present there seems to be just as great a break in the flora as there is, in Bengal at least, in the stratigraphy. The most striking distinction is that the prevalent forms in the lower Gondwánas are *Equisetaceæ* and ferns of the *Glossopteris* type, *Cycadeaceæ* being rare, whilst in the upper Gondwánas, and especially in the Rájmahál group, *Cycadeaceæ* prevail, their individual abundance being so great that they frequently form the mass of the vegetation. In fact, the Cycads, and especially *Ptilophyllum acutifolium*, are just as abundant and characteristic in the Rájmahál group as *Glossopteris* and *Vertebraria* are in the Damúdas.

Only a single species is found in the Rájmahál group, and also in European strata. This is *Sphenopteris arguta*, found also in the lower oolite of Yorkshire. The specimen referred to *Pterophyllum propinquum* is too fragmentary for certain identification, and the identity of the *Sphenopteris* is by no means free from doubt. Several forms, however, are considered by the various palæontologists who have described them to be allied to European lias and rhætic plants, and a decided opinion has been expressed by Dr. Feistmantel that the Rájmahál group is of liassic age. This conclusion may possibly be correct, but it is on the whole premature, and it is scarcely supported by the evidence. There is certainly not so strong a connection between the Rájmahals and the typical European liassic flora as there is between the Cutch flora and that of the

[1] No sufficient reason has been assigned for the alteration of the original specific name in the case of this species and of the Dictyozamites, nor does it appear desirable that the later term *indica* should replace the much older name *salicifolia* in the case of the *Thinnfeldia*.

English lower oolites, and yet it appears probable that the homotaxis in the latter case is misleading to a certain extent, and that the beds are really upper jurassic. Besides, taking Dr. Feistmantel's own data,[1] no fewer than fifteen of the above species are allied to rhætic species, whilst only three have a close connection with liassic plants, two of these having equally close rhætic relations. It is true that the European liassic flora is poorer than the rhætic, but not in this proportion. On the other hand, six species exhibit affinities with lower oolitic forms. It has also been pointed out by Dr. Oldham[2] that there is a decided connection between some Rájmahál plants and species belonging to the Wealden flora of Europe. Two of the Rájmahál plants, *viz.*, *Gleichenia bindrabunensis* and *Danæopsis rajmahalensis*, are near species found in the upper trias, (Keuper,) most fossil forms of *Gleichenia* being, however, cretaceous, whilst *Macrotæniopteris lata* is quite as nearly allied to the permian *M. abnormis* as to any of the mesozoic forms, and some of the species of *Pterophyllum* also have permian affinities. *Cyclopteris oldhami,*

[1] Pal. Ind., Ser. II, pp. 143, 187. The Rájmahál plants allied to rhætic European forms are said by Dr. Feistmantel to be—

INDIAN SPECIES.		EUROPEAN SPECIES.
Equisetum rajmahalense	allied to	*E. muensteri.*
Thinnfeldia salicifolia	"	*T. decurrens.*
Alethopteris indica	"	*Asplenites rosserti.*
Asplenites macrocarpus	"	*A. ottonis.*
Gleichenia bindrabunensis	"	*Gleichenites microphyllus.*
Tæniopteris macclellandi	"	*T. muensteri.*
Macrotæniopteris lata	"	*T. gigantea.*
Pterophyllum distans	"	*P. (Ctenophyllum) braunianum.*
P. princeps	"	*P. braunsi.*
P. fissum	"	*P. comptum* and *P. minus.*
P. near *P. propinquum*	"	*P. propinquum.*
Otozamites near *O. brevifolia*	"	*O. brevifolia.*
Palissya indica	"	*P. brauni.*
Chirolepis gracilis	"	*C. muensteri.*
C. sp. near *C. muensteri*	"	"

The forms with liassic affinities are—

Equisetum rajmahalense	"	*E. liasinum.*
Tæniopteris macclellandi	"	*T. muensteri.*
Cycadites rajmahalensis	"	*C. linearis.*

Whilst oolitic relations are shewn by—

Sphenopteris arguta, a lower oolitic species.

Hymenophyllites bunburyanus	allied to	*Tympanophora racemosa.*
Alethopteris indica	"	*A. whitbyensis.*
Pterophyllum fissum	"	*P. minus,* a rhætic species also.
Williamsonia sp. near *W. gigas*	"	*W. gigas.*
Araucarites macropterus	"	*A. brodiei.*

[2] Mem. G. S. I., II, p. 321.

Sphenopteris membranosa and *S. hislopi* are also most nearly connected with Palæozoic forms. Taking the whole evidence, it appears that the Rájmahál flora has no very marked connection with any single European group, and although the facies does not differ so widely from that of all European fossil floras as in the case of the Damúda series, it is only possible to indicate the relative position by an approximation. Generally, the Rájmahál flora is most nearly allied to rhætic and lower oolite, but it is by no means improbable that India in Rájmahál times was separated from the land then existing in the European area and that the two belonged to distinct botanical regions, since, out of about fifty species, only one can be identified with a European fossil plant.

Relations to Uitenhage flora of South Africa.—Again, however, as in the case of the Damúda series, we have some indications of a connection with South Africa. The resemblance of the South African Karoo flora to that found in the Damuda rocks has already been noticed. Above the Karoo beds there is found another great series known by the name of Uitenhage,[1] the upper portion of which consists of several groups containing marine fossils, and ranging in age from lower to upper jurassic, the uppermost beds having some neocomian forms mixed with the jurassic species; whilst beneath all the marine beds, immediately above the Enon conglomerate at the base of the series, there is found in one locality, Geelhoutboom on Sundays river, Uitenhage, a set of plant-bearing beds, the flora of which presents some affinities to that of the Rájmahál group. The following is a list of the plants described, with their allies in the Rájmahál flora:—

FILICES.

Pecopteris atherstonei. } Allied to the Rájmahál species *Alethopteris*
P. rubidgei. } *indica.*
P. africana.
Asplenites lobata, identical with the Rájmahál species, *Pecopteris lobata.*
Sphenopteris antipodum.
Cyclopteris jenkinsiana, allied to *C. oldhami.*

CYCADEACEÆ.

Palæozamia (Otozamites) recta.
P. (Podozamites) morrisi.
P. rubidgei.
P. (v. Pterophyllum) africana.

CONIFERÆ.

Arthrotaxites, sp. allied to *Echinostrobus indicus.*

[1] Tate and Rupert Jones, Q. J. G. S., 1867, pp. 144, 149, &c.: Stow, Q. J. G. S., 1871, p. 497.

The alliances between the Cycads are vague. *Palæozamia rubidgei* has some slight resemblance to *Pterophyllum distans*, and *P. africana*, if it be a *Pterophyllum*, may be allied to *P. morrisianum*, but the connection is not close. The Cycads indeed appear more nearly related to some lower oolitic European forms. The *Pecopteris lobata* appears however to be the commonest plant of the formation, and *Cyclopteris jenkinsiana* is also found in abundance.

Relations to Jabalpur and Cutch floras.—Owing to the prevalence of the same species of *Ptilophyllum* in both, and to a general resemblance in the flora, it was long supposed that the Jabalpur group and the plant-bearing beds of Cutch (Kachh) were the equivalents of the Rájmahál group. A more careful examination of the plants has shewn that there are important differences between the floras of the different localities, and, judging by the facies of each flora, Dr. Feistmantel has come to the conclusion that the Rájmahál group is older than the other two. It must be borne in mind that the Rájmaháls have never been found in contact with either of the other groups,[1] and that the view of their relative ages is based upon the relations of their fossil floras to the plants found in European rocks. Still the circumstance that, near Cocanada, beds occur containing marine fossils, identical with those of strata which are associated with the Cutch plant-beds, and that these fossiliferous bands have been identified, on apparently good evidence, with some strata which are found, near Ellore, overlying a formation with Rájmahál fossils, tends strongly to confirm Dr. Feistmantel's views.

Ragavapuram shales.—Upon the Golapilli beds in the neighbourhood of Ellore[2] there is found resting a thin band of white and buff shales having a few interstratifications of sandstones towards the base. No unconformity has been detected between these shales and the Golapilli sandstones, but there appears to be some difference in the flora, for, whereas the plants found in the Golapilli sandstones are, without exception, either Rájmahál forms or else species peculiar to the beds, the former being far more numerous than the latter, the flora of the overlying shales comprises a few species allied to Jabalpur plants in addition to several forms common to the beds below. The shales have been called Ragavapuram, from a village situated about 26 miles

[1] The case of the Kota-Maleri beds will be found mentioned below. The supposed identification of the Rájmahál group in the Godávari valley, near Sironcha, appears to have been based on insufficient evidence.

[2] King, Rec. G. S. I., X., p. 56; Feistmantel, Pal. Ind., Ser. III, 3, p. 163.

north-north-east of Ellore. The plants found comprise the following species [1] :—

Tæniopteris (*Angiopteridium*) *spathulata*.
T. (*Angiopteridium*), sp.
Ptilophyllum cutchense.
P. acutifolium.
Pterophyllum, sp.
Taxites, sp.
Gingko crassipes.

The two last are allied to Jabalpur forms. With the plants are some marine shells, chiefly casts; amongst these are some *Ammonites* apparently allied to middle jurassic species, the principal form being near *A. opis*, but distinguished by having the ribs simple throughout. *A. opis* belongs to the subgenus *Stephanoceras* and to the group of *A. macrocephalus*, and is found in the Chari and Katrol beds of Cutch (Callovian and Oxfordian). Besides the ammonites, *Leda*, *Pecten*, *Gervillia*, &c., occur, the *Leda* being especially common and characteristic.

The Ragavapuram shales cannot be more than 100 feet thick, and they are overlapped at both ends by Tripetty sandstones. They closely resemble some shales found further down the coast near Ongole and containing a similar flora, and they appear to represent the Sripermatúr group near Madras.

Tripetty sandstones.—Above the shales just noticed there is another thin band of dark brown and red sandstones and conglomerates, chiefly ferruginous, with silicious and argillaceous bands and beds of concretionary clay ironstone. Towards the bottom these sandstones become softer and less ferruginous. In the main area, near Ellore, the Tripetty beds are only 40 feet thick. They are named from a pagoda called Chinna (little) Tripetty, which stands upon a scarp composed of them, about 20 miles north-north-west of Ellore.

The Tripetty beds, in the main area, have only yielded fossil wood, but from some outlying patches supposed to belong to the same band near Innaparazpolliam, about 24 miles north by east of Cocanada, Mr. King obtained two *Trigoniæ*,—*T. smeei* and *T. ventricosa*,—both of which are characteristic of the Umia beds of Cutch. *T. ventricosa* is also very abundant in some upper jurassic beds, forming the uppermost group of the Uitenhage series in South Africa.

The sequence of upper Gondwána beds in the neighbourhood of Ellore is very instructive. The whole series rests unconformably on the Kámthis (lower Gondwána), and although the whole thickness of the upper Gondwána series is trifling, apparently not exceeding 200 or 300

[1] In the list given in Pal. Ind., Ser. II, 3, p. 3-165, both Ragavapuram and Sripermatúr forms were included.

feet, it comprises representatives of the Rájmahál and Umia groups, and of an intermediate formation. It is evident that these beds must represent between them a considerable period of geological time, for it is scarcely probable that the Rájmahál beds can be much newer than lower jurassic (Bathonian), and it is certain that the Tripetty beds, if they are the equivalents of the Umia group, must be at the top of the jurassic series, whilst the intermediate Ragavapuram shales are perhaps, judging from their *Ammonites*, on about the same horizon as the Chári beds of Cutch (Oxfordian or Callovian). Yet these thin bands exhibit no marked unconformity. The middle group is overlapped at both ends, it is true, but there is no sign of any important break. It is clear that the country must have undergone very little disturbance in the interval between the deposition of the different groups; and judging from this instance, it is impossible to argue from the small amount of discordance between successive sub-divisions of the Gondwána series, that the period of time which elapsed between the different groups was of small amount. But for the fossils, no notice would, in all probability, have been taken of the distinctions between the different beds at Ellore, and many similar sub-divisions might be made in such groups as the Kámthi or Pachmarhi if the strata were fossiliferous.

Sripermatur group.—As already mentioned, the upper Gondwána beds near Madras are divided into two groups,[1] the lower of which has been named from Sripermatúr, a town about 25 miles west-south-west of Madras, and a well-known locality for fossil plants. This group is partly composed of white shales containing plants, and associated with sandstones, grits, and micaceous sandy shales. Conglomerates occur, especially towards the base, where they are coarse and occasionally contain boulders of great size, but all conglomeratic beds in this group are of loose texture and not compact.

It is in the Sripermatúr shales that the fossils of this formation are found. They consist of both animals (marine shells) and plants, the two being found in the same beds. The shells, however, are ill-preserved, and have not been determined. They comprise two or three species of *Ammonites* and several lamellibranchiate bivalves, amongst which forms of *Aucella* are particularly common.[2]

[1] Foote, Mem. G. S. I., X, p. 64.

[2] In the Ongole plant beds, considered to be on the same approximate horizon as the Sripermatúr shales, the caudal portion of a crustacean has been found, which belongs to the genus *Eryon*, and appears to have some resemblance to the liassic species *E. Barrovensis*; Feistmantel, Rec. G. S. I., X, p. 193, figs. 1, 2, 3. A comparison of these figures with that of *E. Barrovensis*, Q. J. G. S., 1866, p. 495, Pl. XXV, fig. 1, will shew, however, that there are some important differences between the two forms. In the paper quoted, the locality of the fossil was, by mistake, said to be Sripermatúr.

a list of the plants as determined by Dr. Feistmantel, the species common to the Jabalpur group being marked with an asterisk (*), whilst those found in the Rájmahál group are thus indicated (†) :—

FILICES.

* *Alethopteris whitbyensis.*	† *Tæniopteris* (*Angiopteridium*) *spathulata.*
† *A. indica.*	*Thinnfeldia*, sp.

CYCADEACEÆ.

* † *Ptilophyllum cutchense.*	*Otozamites*, 2 species undescribed.
* † *P. acutifolium.*	*Pterophyllum*, 2 sp. undescribed.
† *Dictyozamites falcatus.*	*Cycadites*, sp.
* *Otozamites hislopi.*	*Cycadolepis*, sp.
O., sp. allied to *O. tenuatus.*	

CONIFERÆ.

* † *Palissya indica.*	*Taxites*, sp., found also in the Ragavapuram shales.
† *P. conferta.*	*Pachyphyllum*, sp., allied to *P. peregrinum.*
* *Echinostrobus expansus.*	
* *Araucarites cutchensis.*	

Judging from the above list the Sripermatúr beds appear to be of rather later age than the Rájmahál and Golapilli group, and, like the Ragavapuram shales, to be intermediate between those formations and the Jabalpur group.

Sattavedu group.—The upper group receives its name from the Sattavedu hills, a series of moderately elevated ridges lying on the border of the North Arcot and Madras districts, about 35 miles north-west of Madras. The rocks consist of immense beds of coarse, compact conglomerate, with sandstones and grits intercalated. The conglomerates are chiefly composed, in the typical locality, of quartzite pebbles in a hard cement, sometimes argillaceous and ferruginous, sometimes calcareous and silicious. In other areas, the pebbles are of granite, syenite, and quartz. The conglomerates are several hundreds of feet in thickness.

The junction of the group with the Sripermatúr beds is ill seen, but the two appear to be conformable. Only imperfect plant-remains have been obtained from the Sattavedu group; the best preserved appears to be a *Dictyozamites*. It is probable that this group is only the upper portion of the Sripermatúr beds.

Trichinopoly or Utatur plant-beds.—Beneath the cretaceous rocks, near Trichinopoly, there are found,[1] cropping out along the western ridge of the cretaceous area, and resting upon metamorphic rocks, several small patches of soft shales and sandstones with a coarse conglomerate, containing large rounded masses of gneiss, at the base. The shales are, as a rule, micaceous and sandy; in places they abound in impressions of

[1] H. F. Blanford, Mem. G. S. I., IV, p. 39.

leaves, chiefly of *Ptilophyllum,* but these markings are frequently ill-preserved, and from the friable nature of the rocks, specimens are very difficult to transport without obliteration. Owing to the softness of the material, the impressions originally obtained have perished, but they were said to comprise *Ptilophyllum acutifolium, P. cutchense, Gleichenia bindrabunensis,* and one of the species of *Tæniopteris* found in the Rájmahál group.

Kota-Maleri group.—The rocks of the Gondwána series in the Pránhita and Godávari valley south of Chánda are still imperfectly known, but two names of localities have been familiar to Indian geologists for many years on account of the discoveries of fossil fish by Dr. Walker and Dr. Bell,[1] and of fish teeth and reptilian bones by Mr. Hislop.[2] The former were discovered at a small village called Kota, on the left bank of the Pránhita or Wainganga, about 8 miles above its junction with the Godávari; the latter were procured at Maledi or Maleri, a village situated 32 miles north-west of Sironcha, about 21 miles west of the Pránhita, and 30 miles north of the Godávari.

The rocks of the Kota-Maleri group are somewhat similar in character to those of the Panchets of Bengal. The most distinctive beds are red and green clays with soft white or greenish argillaceous sandstones. There is, however, an entire absence of the yellowish-green micaceous sandstones and shales, so characteristic of the Panchets. With the clays of the Kota-Maleri groups are associated flaggy beds of somewhat earthy grey limestone, and thick sandstones of various colours, usually containing small nodules of green clay. Clays are less abundant in the upper portion of the group, which consists chiefly of coarse and loosely compacted sandstone, varying in colour, and containing fragments of pink and buff shale arranged in bands. Similar bands of shale fragments in sandstone are found at a lower horizon, but they are more common above the clays forming the lower part of the group.

The limestones contain fossil fish at Kota, whilst reptilian remains (*Hyperodapedon* and *Parasuchus*) and *Ceratodus* teeth, abound in some places in the clays, and *Estheriæ* and portions of insects have been found in the shaly beds associated with the limestones. Nothing definite has hitherto been ascertained of the thickness of this group. It rests unconformably on the Kámthis, and for a long time it was supposed that the Maleri beds represented the Panchets of Bengal, whilst the limestones of Kota were considered to be of later date on account of their containing liassic forms of fish. The discovery, however, in the Maleri beds, of plant-

[1] Q. J. G. S., 1851, p. 272; 1852, p. 230; 1853, p. 351; 1854, p. 371.
[2] Mem. G. S. I., I, p. 295; Q. J. G. S., 1864, p. 280, &c.

remains identical with those of the Rájmahál and Jabalpur groups has rendered it evident that the former must be transferred to the upper Gondwána series, and it has also been shewn that the Kota limestones are intercalated in the clays and sandstones of the Maleri beds, although these limestones are above the *Ceratodus* and *Hyperodapedon* strata of Maleri itself.[1] Remains of *Hyperodapedon* have, however, been found in clays, precisely similar to those of Maleri, and apparently at a much higher horizon than the Kota limestones.

This alteration of the views formerly held as to the relations of the Kota-Maleri beds is supported to some extent by stratigraphical characters. Mr. King separates from the Kota-Maleri beds an overlying group which he calls "Chikiala sandstones," from the village of Chikiala on the Pránhita, 15 miles north of Sironcha. These upper sandstones comprise vitreous ferruginous conglomerates, hard silicious and argillaceous conglomerates, and bands of concretionary clay ironstones, all having a marked resemblance to the beds of Tripetty, near Ellore; and Mr. King suggests that the two formations are identical. At the base of the typical Kota-Maleri beds also, in the neighbourhood of Sironcha, are some sandstones which it has been thought may represent the Golapilli (Rájmahál) group, but upon this point further evidence is desirable, there being no stratigraphical characters of importance to support the conclusion. The palæontological evidence will be mentioned presently.

Palæontology.—The following is a list of the fossils hitherto procured:—

ANIMALS.

CRUSTACEA.

Estheria kotahensis.	*Candona kotahensis.*

INSECTA.

Undetermined.

PISCES.

Lepidotus deccanensis.	*Tetragonolepis analis.*
L. longiceps.	*T. rugosus.*
L. breviceps.	*Dapedius egertoni.*
L. pachylepis,	*Ceratodus hunterianus.*
L. calcaratus.	*C. hislopianus.*
Tetragonolepis oldhami.	*C. virapa.*

[1] Hughes, Mem. G. S. I., XIII, p. 81; King, Rec. G. S. I., X, p. 61. Both geologists agree in classing together the Kota and Maleri beds. Several details are from MS. reports by the geologists mentioned.

REPTILIA.

Hyperodapedon, sp.	*Parasuchus*, sp.

PLANTS.

FILICES.

Tæniopteris (Angiopteridium), sp. The species found also in the Ragavapuram shales.

CYCADEACEÆ.

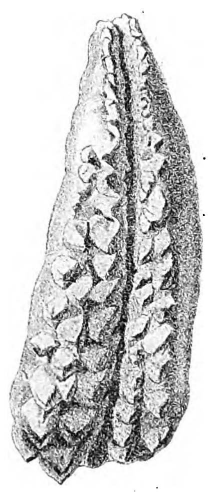
Ptilophyllum acutifolium.	*Cycadites*, sp.

CONIFERÆ.

Palissya conferta.	*Chirolepis*, sp. near *C. muensteri*.
P. jabalpurensis.	*Araucarites cutchensis*.

A few fragmentary impressions of bivalve shells have also been found. They are not sufficiently perfect to enable the genus to be determined, and it is uncertain whether they are fresh-water or not, but probably they are. They may belong to the *Unionidæ*.

Despite the very imperfect examination which these rocks have hitherto received, they have already yielded more genera of animals than any other Gondwána groups, more even than the Panchets. The question of homotaxis has consequently been much discussed, and a few remarks on it are necessary here.



Anterior extremity of right upper jaw of *Hyperodapedon* from Mángli. Natural size.

The genus *Parasuchus*[1] belongs to a typically mesozoic group of crocodiles with biconcave vertebræ. It is placed by Professor Huxley in the same section of this family with the European genera *Belodon* and *Stagonolepis*, which are almost confined to triassic rocks in Europe, some remains of *Belodon* having also been found in rhætic beds.

The genus *Hyperodapedon*[2] belongs to a peculiar group of lizard-like Saurians, considered by some naturalists to form a distinct order, equivalent to the snakes or lizards, and known as *Rhynchocephala*,[3]

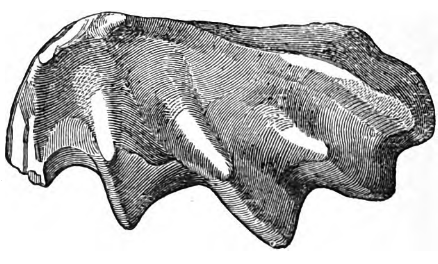
[1] This genus does not appear to have been described, but it has been so frequently referred to in the Survey publications that it is scarcely possible to treat the name as a merely manuscript designation, liable to be changed at any time. See Q. J. G. S., 1875, XXXI, p. 427.

[2] Huxley, Q. J. G. S., 1869, p. 138.

[3] Günther, Phil. Trans., 1867, CLVII, p. 626.

but classed by others as a sub-division of the *Lacertilia*. This group is represented in the living fauna only by two species of *Hatteria* found in islands near New Zealand. *Hyperodapedon* has hitherto been found in Europe only in triassic rocks.

The fish are all characteristically mesozoic. The genus *Lepidotus* ranges from the lias to the lower chalk, the Kota species being considered by Sir P. Egerton, who described them, as showing liassic or oolitic



Right palatal tooth of *Ceratodus hislopianus* from Mángli. Natural size.

affinities. *Tetragonolepis* is only known from liassic beds; *Dapedius* also is liassic. *Ceratodus*, on the other hand, is, in Europe, chiefly found in triassic rocks, in which the genus is rather extensively distributed.[1] Some forms have, however, been found in rhætic beds, and one in the Stonesfield slate (lower oolitic). Recently the same genus has been discovered living in Australia.

Neither the *Estheria* nor the *Candona* can be considered as very characteristic of age.[2] The former belongs to the same group as *E. minuta*, so abundant in the triassic and rhætic beds of Europe, but represented by closely allied forms in various rocks from the carboniferous to the present day. The genus *Candona* has a similar range, and there is nothing distinctive in the Kota species.

The insects have not been examined, and it only remains to notice the plants. These have chiefly been obtained from localities in the neighbourhood of Jangáon, south-west of Sirpur, and some reptilian remains, identical with those of Maleri, were found in clays associated with the plant beds. The two species of plants first discovered by Mr. Hughes in these beds near Jangáon were *Palissya jabalpurensis* and *Araucarites*

[1] For descriptions and figures of the species of *Lepidotus, Tetragonolepis,* and *Dapedius,* by Sir P. Egerton, see Q. J. G. S., 1851, p. 272; 1854, p. 371; and Pal. Ind., Ser. 4, Pt. 2. The *Ceratodi* are described by Mr. Miall in the publication last named and (originally) by Dr. Oldham; Mem. G. S. I., I., p. 295.

[2] T. R. Jones, Mon. Foss. Estheriæ, p. 78: Q. J. G. S., 1863, p. 149.

cutchensis, and as these are both Jabalpur forms, it was supposed[1] that the Kota-Maleri beds represented the Jabalpur group. At the same time *Palissya conferta* and a *Chirolepis* very close to *C. muensteri* were obtained by Mr. King at Anáram, on the right bank of the Pranhita, from sandstones underlying the fish beds of Kota on the left bank. The same two species had been found by Mr. Fedden in 1873 near Jangáon, and as both these forms occur in the Rájmahál beds of Golapilli, whilst neither is found in the Jabalpur or Cutch groups, it was inferred that the sandstone at the base of the Kota-Maleri group—the Sironcha sandstones of Mr. King's classification—should be classed as Rájmaháls. *Palissya conferta*, or a form undistinguishable from it, has, however, sinec been obtained by Mr. Hughes in undoubted Kota-Maleri beds, associated with a *Tæniopteris* and some other plants, found also in the Ragavapuram shales, and *Palissya conferta* itself has been detected in the Sripermatúr group. Several species of plants are, moreover, common to the Rájmahál and Kach-Jabalpur groups; the typical flora of the first has hitherto never been found in Central India, but is restricted to a series of beds confined to the east coast, and it would, therefore, be premature to identify the sandstones, near Sironcha and Jangáon, containing *Palissya conferta* and *Chirolepis*, with the Rájmaháls of Eastern India, even if it were certain that these sandstones were inferior in position to the Maleri clays.

Quite recently, the discovery of *Ptilophyllum*, the characteristic genus of the upper Gondwána series, in the Kota-Maleri beds, has confirmed the idea first suggested by the conifers, that this group must be classed as upper Gondwána.

It will be seen that the evidence as to age is conflicting, so long as these beds are compared with the fauna and flora of European formations. Some of the animal remains point to a triassic epoch; others have liassic affinities, whilst the plants have a jurassic or rhætic facies. On the other hand, *Ceratodus* and *Hyperodapedon*, characteristically triassic types in Europe, are allied to animals still living in Australia or New Zealand. The Kota-Maleri beds, indeed, serve as a warning against placing too much reliance upon the affinities of fossil terrestrial faunas and floras with those of Europe, in estimating age or even homotaxis. Until the plant-remains of the Kota-Maleri group were discovered, the Maleri beds were classed with the Panchets, partly on account of their mineral character, but more because they appeared to be connected by homotaxis with the same European formation, the trias, of which the Panchet group was considered to be representative. The Kota rocks, also,

[1] Rec. G. S. I., IX, pp. 132-35.

on account of their fauna, were considered higher and assigned to a liassic horizon. The relations of these beds to European formations have only been rendered more obscure by the discovery of the plants contained in them, but as several of those plants are common to the Jabalpur and Rájmahál groups, which are well developed at no great distance, it appears best to refer the Kota-Maleri beds to the same approximate horizon as the Ragavapuram and Sripermatúr groups, leaving it for future research to determine how far exact equivalents of the Rájmahál, Sripermatúr, and Jabalpur sub-divisions may or may not be distinguished in the strata classed together as Kota-Maleri.

Jabalpur group.—In the first account of the central portion of the Narbada valley,[1] a group of rocks was distinguished as "upper Damúda." It was, however, pointed out at the time that this group was not only unconformable to the "lower Damúda," but that it contained a very different flora. When, subsequently, a true upper Damúda group was found in the Ránigani coal-field, it became desirable to distinguish the Narbada beds by a different name, and as they are well developed in the immediate vicinity of Jabalpur, they have been named from that town.

The Jabalpur group consists of clays, shales, and earthy sandstones with some thin beds of coal. The clays and soft shales, which are the most characteristic beds of the formation, are pale-coloured, usually white, pale lavender-grey, or pale red. The sandstones are generally coarse and conglomeratic. Carbonaceous shales are met with in several places, and, occasionally, one or more thin bands of jet-coal, very different in character from the coal of the Damúda formation. Limestone is rare. At the base of the formation, when resting upon gneissic rocks, there is frequently found a coarse, compact sandstone, so hard and compact as almost to resemble a quartzite. It is often conglomeratic, and the matrix containing the pebbles consists of white earthy rock in a porcellanic condition. Occasionally, but rarely, this bed is calcareous.

The thickness of the Jabalpur formation does not appear to have been determined with any accuracy. It is, however, of no great vertical extent, and, so far as is known, it nowhere exceeds 1,000 feet. The relations of the Jabalpur group to the underlying Mahádevas have not been examined in detail, but there appears to be conformity in general between the two.

[1] J. G. Medlicott, Mem. G. S. I., II, p. 176. The Jabalpur formation was at this time not clearly distinguished in places from the Mahádevas. The former was supposed to be the lower; in reality the Jabalpur formation is not only newer than the Mahádeva, but it appears to be the latest member of the whole Gondwána series, and to contain several plants found also in the Umia group of Cutch. Further accounts of the Jabalpur group will be found in Rec. G. S. I., IV, p. 75; and Mem. G. S. I., X, p. (142).

Palæontology.—The following is a list of the fossils found in this formation,[1] those found also in the Umia beds of Cutch being marked with an asterisk thus (*); whilst those also met with in the Rájmahál group are distinguished by a (†):—

FILICES.

† *Sphenopteris*, sp. allied to *S. arguta*.
Dicksonia, sp.
Alethopteris medlicottiana.
* *A. whitbyensis.*
A. lobifolia.
Tæniopteris (*Macrotæniopteris*) *satpurensis.*
Glossopteris, sp. (fragments only).
Sagenopteris, sp.

CYCADEACEÆ.

Pterophyllum nerbuddaicum.
*† *Ptilophyllum cutchense.*
*† *P. acutifolium.*
Podozamites lanceolatus.
P. spathulatus.
P. hacketi.
Otozamites hislopi.
O. gracilis.
O. distans.
O. angustatus.
† *Williamsonia*, near *W. gigas.*
Cycadites allied to *C. gramineus.*

CONIFERÆ.

*† *Palissya indica.*
P. jabalpurensis.
* *Araucarites cutchensis.*
* *Echinostrobus expansus.*
E. rhombicus.
Brachyphyllum mammillare.
Taxites tenerrimus.
Gingko lobata (*Cylopteris* or *Baiera lobata*).
Phœnicopsis.
Czekanowskia.

The following species, according to Dr. Feistmantel, are either found in the lower jurassic beds of England, or represented by very closely allied species:—

Sphenopteris arguta.
Alethopteris whitbyensis.
A. lobifolia.
Podozamites lanceolatus.
Williamsonia, near *W. gigas.*
Brachyphyllum mammillare.
Echinostrobus expansus.
Araucarites cutchensis, near *A. phillipsi.*
Gingko lobata near *G. (Cyclopteris) digitata.*

whilst one species, *Otozamites gracilis*, is liassic. *Alethopteris whitbyensis* and *Podozamites lanceolatus* are also found in several localities in Western and Northern Asia, and in Eastern Siberia they are associated with *Cycadites gramineus*, *Czekanowskia*, *Phœnicopsis*, and some other plants nearly allied to Jabalpur species.

[1] As determined by Dr. Feistmantel. See Rec. G. S. I., 1876, IX, p. 125; Pal. Ind. XI, 2. The following are figured on plate X:—

Figure 1. *Alethopteris medlicottiana.*
„ 2. *Otozamites gracilis.*
„ 3. *O. hislopi.*
Figures 4 & 5. *Podozamites lanceolatus.*
Figures 6 & 7. *Brachyphyllum mammillare.*
Figure 8. *Palissya jabalpurensis.*
„ 9. *P. indica.*
Figures 10 & 11. *Araucarites cutchensis.*

It will be seen that there are nearly as many Rájmahál as Umia species found in the Jabalpur group, so far as the flora has hitherto been determined. It should, however, be remembered that the known species of the Rájmahál flora are nearly fifty in number, while those of the Umia flora are much less numerous (about twenty-two[1]), five of the former and six of the latter being found in the Jabalpur beds, which are distinguished by a conspicuous want of many of the commonest and most characteristic Rájmahál plants, such as the broad-leaved species of *Pterophyllum*.

It must also be borne in mind that there is a marked connection between the Jabalpur and Cutch beds in the considerable proportion of species in both common to the lower oolitic rocks of England. *Sphenopteris arguta,* one of the plants common to the Rájmaháls and Jabalpur, but hitherto not found in the Umia beds of Cutch,[2] is also a lower oolitic species. But too great stress must not be laid on identifications of Indian fossil plants with European, as a guide to age.

On the whole, the Jabalpur beds are probably on nearly the same horizon as the Umia beds of Cutch, but possibly represent a period intermediate between the Cutch and Rájmahál groups, though nearer to the former. At the same time the circumstance that no representative of the Jabalpur flora has yet been found on the east coast of the Indian Peninsula, whilst the Rájmahál flora is confined to the neighbourhood of the east coast, suggests that the distinction may be due to the beds having been formed in regions with a different flora. But bearing in mind the large amount of evidence which exists to shew that the greater part, if not the whole, of India proper was a land area in Gondwána times, this idea of the country having been divided into distinct botanical regions is less probable than the theory of a difference in age between the Rájmahál and Jabalpur groups.

Umia group of Cutch (Kachh).—This group is only mentioned here because of its relations to the uppermost beds of the Gondwána series. The name Umia is derived from a village about 50 miles north-west of Bhúj, the chief town of Cutch. The group will receive a fuller description under the head of the jurassic formations, and an account will be given of its mineral character and fossil animals.

The especial interest of this group in connection with those just enumerated is due to the fact that, in Cutch, beds containing plants, several of which are identical with those of the Jabalpur beds, are interstratified with rocks yielding marine fossils.

[1] Dr. Feistmantel enumerates twenty-eight in his Memoir, but some are varieties only, others stems not identified generically.

[2] It is, however, found in Cutch at a lower horizon.

The following is a list of the plants from the Umia beds [1] :—

ALGÆ.

? *Chondrites dichotomus*.—Perhaps founded on a badly perserved coniferous stem.

FILICES.

* *Tæniopteris* (*Oleandridium*) *vittata*.
T. densinervis.
* *Alethopteris whitbyensis*.
Pecopteris tenera.
* *Pachypteris specifica*.
P. brevipinnata.
Actinopteris, sp.

CYCADEACEÆ.

† *Ptilophyllum cutchense*.
† *P. acutifolium*.
P. brachyphyllum.
Otozamites contiguus.
* *O. imbricatus*.
* *Otozamites* near *O. goldiæi*.
* *Cycadites cutchensis*.
* *Williamsonia blanfordi*.
Cycadolepis pilosa.

CONIFERÆ.

Palissya bhoojoorensis.
† *P. indica*.
* *P.* near *P. laxa*.
* *Pachyphyllum divaricatum*.
* *Echinostrobus expansus*.
* *Araucarites cutchensis*.

Those marked thus (*) are represented by the same or closely allied forms in the lower oolitic beds of Europe, being chiefly found in Yorkshire. Four of the species marked are considered identical with European lower oolitic forms, *viz.*, *Tæniopteris vittata*, *Pecopteris whitbyensis*, *Pachyphyllum divaricatum*, and *Echinostrobus expansus*, the other six being closely allied.

Species thus marked (†) occur also in the Rájmahál group. The forms common to the Jabalpur beds have already been mentioned.

The homotaxis of the Umia flora is thus shewn to be lower oolitic, yet these beds, as will be explained more fully when treating of the jurassic rocks of Cutch, rest upon strata with marine fossils, amongst which are *Cephalopoda* and some other mollusca with upper oolitic (Portland and Tithonian) affinities, and are immediately overlaid by a bed containing neocomian *Ammonites* and *Crioceras*.

Narha beds.—At a somewhat lower horizon in the rocks of Cutch, a few plants have been found near a village named Narha, in the northern part of the province,[2] in beds interstratified with the Katrol group, the *Cephalopoda* of which are considered by Dr. Waagen as corresponding to

[1] Pal. Ind. Ser. XI, 1; Rec. G. S. I., IX, p. 29. The following Umia species are figured on Plate XI :—

Figure 1.	*Tæniopteris vittata*.	
„ 2.	*Alethopteris whitbyensis*.	
Figures 3 & 4.	*Ptilophyllum cutchense*.	
Figure 5.	*Echinostrobus expansus*.	
„ 6.	*Pachyphyllum divaricatum*.	
Figures 7 & 8.	*Araucarites cutchensis*.	

[2] Mem. G. S. I., IX, p. 213; Pal. Ind., Ser. XI, 1, p. 80.

those of the Kimmeridge and Upper Oxford beds of Europe. These plants consist of the following species :—

Sphenopteris cf. *arguta.*	*Otozamites* cf. *contiguus.*
Alethopteris whitbyensis.	*Araucarites cutchensis.*

The three last are apparently identical with species found in the Umia beds, whilst *Sphenopteris arguta* is an English lower oolitic species, found also in the Jabalpur and Rájmahál groups. The *Alethopteris* and *Araucarites* are also Jabalpur forms. This evidence, so far as it goes, tends to shew a great persistency in the flora, and it may indicate that the Jabalpur beds are a little older than the Umia group, since the connection of the flora found in the Katrol beds of Narha with that of the Jabalpur group is quite as strong as with the Umia plant fossils.

CHAPTER VII.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF COAL-FIELDS, ETC.

Distribution of Gondwána basins — Relations to existing river valleys — Groups of basins — Origin of different groups of basins — I, RÁJMAHÁL REGION — Tálchirs — Damúdas — Distribution of Damúdas and Dubrájpur group — Rájmahál group — II, BIRBHÚM, DEOGARH, and KARHARBÁRI REGION — A, Small basins of Birbhúm, Deogarh, etc. — Tangsuli — Kandit Karayah — Sahajori — Jainti or Karaun — B, Small basins of North-Eastern Hazáribágh — Karharbári, etc.

Distribution of Gondwana basins.—The general distribution of Gondwána basins in India has already been described, but in proceeding to give further details of the separate areas in which these rocks are found, it is convenient to divide the scattered tracts into groups and sub-groups. To a certain extent this grouping is simple and natural, there being in some cases several Gondwána basins at no great distance from each other, in all of which the same sub-divisions of the series are represented. A typical case occurs in the Damúda valley. But still there is frequently much difficulty in assigning definite limits to the several groups, since most of them tend to pass into each other where the basins of one group approach those of another.

Relations to existing river valleys.—If the view which, as previously mentioned, is held by some Indian geologists, be correct, and the beds of the Gondwána series were originally deposited in river basins [1] closely approximating to those of the streams which now drain the country, it ought to be simple to group the existing representatives of the series according to the river valleys in which they occur. But a glance at the map will shew that the largest and geologically most important Gondwána area known—that of the Sátpúra region—is situated partly in the drainage of the Narbada, partly in that of the Godávari, whilst there is considerable probability that the Gondwána beds are continuous beneath the covering of Deccan traps with those of the South Rewah [2]

[1] Rec. G. S. I., 1870, Vol. III, p. 5.

[2] It is as well to call attention here to the circumstance that the volcanic outbursts of the Deccan trap must have obliterated all pre-existing valleys, and consequently if the direction and area of the present river valleys correspond in any way with those of pre-trappean times, it can only be by accident.

and Sohágpur field, which forms in places the watershed between the Son, a tributary of the Ganges, and the affluents of the Máhánadi, and extends for some distance into the valleys of both rivers. In this case, therefore, some other guide to the principle on which the different basins should be grouped must be detected. If the Gondwána series, as all Indian geologists believe, are fluviatile deposits, either the whole were accumulated in one great system of river valleys or in several detached drainage areas. The extent of country over which the Gondwána rocks are known to occur is not by any means too great for these beds to have been deposited by one river. The whole area scarcely exceeds the present alluvial plain of the Ganges, which is only a river of the second magnitude, and all might be easily comprised within the deposits of such streams as the Mississipi or Obi. It is probable that if the Gondwánas were accumulated in different river basins, there would be a well-marked petrological distinction between the corresponding groups from top to bottom; if all the beds were deposited in one great basin, there might still be distinctions in places due to the different forms of the detritus derived from the pre-existing rocks in various parts of the area, and probably to unequal changes of level, but there would be a tendency to a passage between the beds in different parts of the country.

Groups of basins.—It has been already pointed out that the characters of the Tálchirs and Barákar groups are similar throughout the Gondwána area, and that these groups are almost everywhere found at the base of the series, the few exceptions which occur being mostly in the case of small and detached outliers. So far, therefore, the evidence is strongly in favour of all the Gondwána areas having been deposited in one river valley or system of river valleys. It is the groups above the Barákars, the upper portion of the lower Gondwánas, and the whole of the upper Gondwána series, which vary in the different regions. Partly by means of these higher rocks, and partly by geographical position, we may classify the different basins of the Peninsula as follows:—

I.—Rájmahál region.
II.—Birbhúm (Beerbhoom), Deogarh (Deogurh), and Karharbári region.
III.—Damúda (Damoodur) valley region.
IV.—Son (Soane), Máhánadi, and Bráhmani valleys.
V.—Sátpúra region.
VI.—Godávari valley.
VII.—East Coast region.

The eastern regions, Nos. I and VII, consist of one or two upper Gondwána groups either isolated or resting on some member of the lower Gondwánas. In the Rájmahál hills the upper Gondwánas rest upon the

Barákars, near Ellore on the Kámthis. In the Birbhúm basins only the lowest groups, the Tálchirs and Barákars, are found, but in the Damúda valley there is a magnificent series of lower Gondwána beds, with only a few small outliers of the upper portion of the series, and even these outliers are imperfectly identified. In the Sátpúra basin there appears to be a full representation of the whole series, whilst both in the Máhánadi and in the Godávari valley there is a break above the Barákars, although the upper portion of the lower Gondwána series is represented, and in the Godávari, at all events, some of the upper Gondwána groups are largely developed.

Origin of different groups of basins.—These differences may be due to the circumstance that the main system of river valleys in which the Tálchirs and Barákars were deposited was broken up at the end of the Barákar period, and whilst in some tracts, as in the Damúda valley and Sátpúra hills, beds continued to be deposited, in others denudation may have taken place. The eruption of the Rájmahál traps was probably marked by much disturbance, and they appear to have closed the Gondwána period in Bengal, although higher deposits are found to the west and south. The marked difference between the formations resting upon the Barákar group in the Damúda and Máhánadi valleys respectively may point to the elevation of the Chutia Nágpór highland at a period immediately subsequent to the close of the Barákar epoch, and the rise, though gentle at first and insufficient to produce much disturbance in the lowest Gondwána groups, may have been accelerated subsequently, and have culminated before the period of the Rájmahál outbursts, thus coinciding in time with the main faults of the Damúda valley coal-fields. It is true that no outliers of the Gondwána series have hitherto been discovered on the Chutia Nágpúr highland, and that on the eastern flanks of the plateau the Tálchirs, and occasionally the Barákars also, are found exposed in valleys in a manner which suggests that the lower Gondwána beds occupy the hollows in which they were originally deposited. There is, however, some remarkable evidence in support of the view that high outliers formerly existed, and the occurrence of lower Gondwána rocks in hollows by no means precludes the idea of great changes of level having occurred since the deposition of these beds, since, as already pointed out, the soft Gondwána beds would wear more rapidly than the harder metamorphic rocks on which they rest, and hence the old surface inequalities would have a tendency to be repeated.

One of the highest hills in the western part of the Chutia Nágpúr table-land is that of Mailan Pát, in Eastern Sirgúja.[1] The

[1] All these details are from manuscript notes.

upper part of this hill, which has a flat top, presents the following section:—

	Feet.
1. Laterite, about	100
2. Deccan trap	150
3. Sandstone, calcareous above	50
4. Gneiss	—

The sandstone No. 3, which is referred to the Lameta group (cretaceous), contains in abundance pebbles apparently derived from the lower Gondwána series, and probably from either Barákars or Panchets. So little disturbance has affected the region since Lameta times that it appears more reasonable to infer that these pebbles were derived from beds then existing at a higher level on the Chutia Nágpúr highland than to suppose that the Lameta beds and overlying trap have been raised to their present elevation by a local movement in which the whole neighbouring country did not participate.

There are several examples in the same neighbourhood of lower Gondwána beds apparently raised to considerable elevations. One is the occurrence of Barákar and Tálchir beds at Chopé on the Hazáribágh plateau; a second, the occurrence of sandstones, probably, to judge from their mineral characters, of Barákar age, capping Madaghir hill, 2,500 feet high, about 5 miles north of the northern scarp of the Chutia Nágpúr table-land, and 3 miles west of the Karanpura coal-field; and a third, the existence of outlying masses of Damúda sandstones on the high gneiss hills of Mahtin and Pindura, west of the Chutia Nágpur table-land, on the ridge of hilly ground separating the basins of the Son and Máhánadi rivers.

The preservation of so complete a series of rocks in the Sátpura region is doubtless due to the protective covering of the Deccan trap, and the same preservative agency may have been the cause of so large an area of soft sandstones still remaining in the Godávari drainage and in the upper valley of the Son. In the same manner the traps of the Rájmahál hills have doubtless prevented the removal by denudation of the Barákars exposed on the flanks of the range, and it is quite possible that to the former extension of the same traps to the west and southwest we owe the existence, at the present day, of the valuable coal-fields in the Damúda and Barákar valleys. If this view be correct, and the preservation of the existing Gondwána basins be due to local protective causes, it is probable that the members of the series formerly covered an enormous area, and that by far the greater portion has been removed by denudation. At the same time, this view is by no means generally accepted by Indian geologists, and the opposite opinion, that the original area of

the Gondwána basins differed but little from that now remaining, is held by good observers, who have carefully studied the formations in the field; and it is remarkable, if the Gondwána beds formerly occupied a wide area, that outliers are not more abundant. The outliers which exist are mostly of Tálchir and Barákar rocks—a circumstance which rather favours the view above suggested that these groups were more extensively distributed than later sub-divisions of the system.

I.—Rájmahál region.—It appears best to describe the Rájmahál Gondwána area apart from all others. The upper Gondwána beds are identified by their flora with some of those found in the outcrops along the east coast of the peninsula; but the interstratification of these beds with basaltic lava flows is peculiar to the present tract. The lower Gondwána beds of the Rájmahál hills may have been connected with those of the basins in Birbhúm and the Damúda valley.

1.—Rajmahal Hills.—A range of flat-topped hills with a general direction from north to south, and chiefly composed of basaltic rocks, extends from the Ganges below Colgong to the neighbourhood of Soory in Birbhúm. These hills are usually called the Rájmahál hills from the town of Rájmahál on the Ganges close to their north-eastern corner, whilst the tract of country including them is generally known as the Dáman-i-koh.[1]

To the west of the range lies the great undulating area of metamorphic rocks included in the districts of Bhagalpur and Birbhúm, broken only by occasional isolated peaks; to the east is the alluvium of the Gangetic plain. The River Ganges runs round the northern extremity of the range, and for some distance close to its eastern edge, whilst the original or loop-line of the East Indian Railway skirts the eastern and northern margin of the hill country throughout.

The Rájmahál hills are almost flat-topped; but the plateaus by which they are capped have, in general, a low dip to the eastward, corresponding to the prevailing dip of the rocks. This dip disappears in the northern portion of the hills. The plateaus are extensive, and are inhabited and cultivated. The range is drained and divided by three streams, all of which traverse it from west to east; the Gumáni to the north, running north-east through the Chuparbhita Pass to join the Morel or Morang, which runs nearly from north to south within the hills; the Bansloi, which runs through the Pachwára Pass; and the Bráhmani, which separates the hills of the Dáman-i-koh from the southern portion of the range known as the Rámghar hills.

[1] Foot of the hills. This name was originally applied to the tracts at the western base of the range.

The Gondwána rocks[1] occurring in this tract consist of the following formations:—

	Approximate thickness in feet.
Rájmahál group (chiefly volcanic)	1,500
Dubrájpur group (Mahádeva ?)	450
Barákar	500
Tálchir	?

As already mentioned, the whole of the beds in the southern part of the area dip from west to east, and the hard basaltic lava-flows form scarps to the westward, and dip away gradually to the eastward until the whole of the rocks disappear beneath the alluvium of the Ganges valley. In the northern part of the hill tract the rocks appear to be nearly horizontal. To the south the western boundary of the sedimentary beds, inferior to the traps, is a line of fault running from north by west to south by east. Further to the north these sedimentary beds rest directly upon the metamorphic rocks. The beds beneath the traps are chiefly exposed along the western boundary and in the valleys of some of the streams which traverse the hills: only one instance is known of the appearance of sandstones to the east of the hills. By far the greater portion of the area is entirely composed of basaltic traps, whilst a large tract on the hill-tops is covered with a thick accumulation of laterite.

Talchirs.—The Tálchir formation is very poorly represented in the Rájmahál area, the few tracts of it which are found being apparently only small portions which have escaped denudation. In no other area in Bengal is there so much appearance of irregular overlap of this formation by the Barákar group. The principal localities at which Tálchirs have been detected on the western side of the Rájmahál hills are in several places a few miles east of the small civil station of Godda, one of the patches occupying about 5 square miles of country. There are also two little inliers, one of them surrounded by traps, about 8 to 10 miles further north-north-east, and another small inlier some 20 miles to the south. None of the tracts presents any peculiarities; the beds seen are the usual greenish silts and sandstones, and the boulders so commonly associated with the formation have only been found in the Narganjo tract south of Godda. There is, however, a boulder bed, which may be of Tálchir age, at the base of the Damúda formation on the Bráhmani river, and in one or two other places in the same position.

Damudas.—The Damúda rocks occur also in isolated tracts, separated from each other by larger areas, throughout which higher strata (Dubrájpur

[1] For a complete account by Mr. Ball, see Mem. G. S. I., XIII, pp. (155)-(248).

beds or Rájmahâls), rest directly upon the metamorphics. The principal of these tracts of Damúda rocks beginning from the north are—

1. The Hura coal-field, a tract about 15 miles from north to south at the north-western edge of the hills near Manhiari. This tract commences about 13 miles south-east of Colgong, and lies for the most part outside the range of hills and on the edge of the Gangetic alluvium.

2. The Chuparbhita coal-field at the western end of the gorge through the hills cut by the Gumáni stream, and known as the Chuparbhita Pass. This tract commences about 10 miles south of the last, and is of irregular form, the rocks being partly exposed to the west of the basaltic trap ranges, partly in valleys excavated in the overlying trap. The greatest length is about 8 miles.

3. The Pachwára field, similarly situated to the last, at the western end of the gorge cut by the Bansloi and known as the Pachwára Pass. A considerable area of the Damúda rocks is here exposed, extending about 7 miles from east to west and 6 from north to south.

4. A strip of country about 8 miles long on the western flank of the hills, commencing near Mahuagarhi hill, 5 or 6 miles south of the Pachwára area, and only separated by about 2 miles from the next tract to the southward. With this tract several inliers to the eastward within the range are connected, the latter exposures being surrounded by Dubrájpur beds or trap. The strip west of the hills is traversed by a stream tributary to the Bráhmani called the Gúmra; the principal inlier within the ranges is near a village called Gopikándar.

5. The Bráhmani coal-field, which extends for about 10 miles along the valley of the river from which it is named.

Besides these larger exposures of Damúda rocks, some smaller areas occur, which are for the most part of minor importance. One of these is found at Pathárgháta, about 6 miles below Colgong on the Ganges. Here are a few isolated hills surrounded by the alluvium, and composed of white sandstones and clays resting upon gneiss and capped by trap. One or two isolated outcrops intervene between this locality and the larger exposure to the south-east. Another small patch of Damúda rocks is found at Pir Pahár, 5 or 6 miles north-west of Rájmahál, where several small hills of coarse sandstone occur surrounded by alluvium.[1]

In all the tracts named, except those near Manhiari and Colgong, the Damúda beds are of the usual Barákar characters, and consist of alternations of grit, sandstone, and shale, with occasional beds of inferior coal.

[1] This has been suggested as a suitable locality for boring for coal, and an attempt has been made to explore the rocks, but hitherto without success.

All the coal seams hitherto found in the Rájmahál area are poor and shaly, though many of them are of considerable thickness and can furnish a large quantity of inferior fuel. In the Hura tract the Damúda beds are similar to those of Pathárgháta, and consist of friable felspathic grits, (the felspar decomposed,) and soft white shales with a few thick seams of inferior coal. It has been suggested by Mr. Ball that these beds may belong to a higher horizon, as they present some resemblance to the Ránigan̈j group of the Damúda coal-fields.

The Damúda beds are in many places disturbed and faulted, so as to contrast strongly with the Mahádevas and Rájmahâls resting upon them. The unconformity is well marked and unmistakable, and there appears every reason for supposing that the coal-bearing rocks had in this area been upheaved and denuded until only isolated basins were left, before the deposition of the overlying Dubrájpur grits.

Distribution of Damudas and Dubrajpur beds.—The distribution of these latter beds is most peculiar, and in order to explain it and at the same time to give a few further details of the Damúdas, it is as well briefly to describe the sedimentary beds intervening between the traps and the metamorphic formations on the west flank of the Rájmahál hills, beginning from the north. South of Manhiari, the Damúdas of the Hura field are found to be only 60 or 70 feet thick, resting upon the gneiss and capped by trap with inter-trappean layers, the Damúda beds being the white argillaceous shales and sandstones, as at Pathárgháta. A few miles to the southward these latter beds become thicker and more carbonaceous, and contain seams of inferior coal. They, however, thin out again further south, and just before they disappear, beds of the Dubrájpur group come in below the traps. A few miles farther south, near a small Santhál village called Simaldhap, the trap rests directly on the metamorphic rocks. There are but two other instances of these two formations being in contact; one is about 12 miles further south, the other a short distance to the eastward, within the Chuparbhita Pass. The trap near Simaldhap rests upon the gneiss for about a mile, when the Dubrájpur group of rocks again comes in between the two. This Dubrájpur group has already been described in the last chapter, it differs widely in character from the Damúdas, and consists of coarse grits and conglomerates, often ferruginous, containing quartz and gneiss pebbles, with occasionally hard and dark ferruginous bands.

At the Chuparbhita Pass the Damúda rocks come in again beneath the Dubrájpur beds and run up the lateral valleys: the character of the Damúdas, here and to the southward, is more that of typical Barákars. For some miles to the north-east on the sides of the pass, the Dubrájpur grits intervene below the traps, but at length they thin

out, and the volcanic rocks rest directly on the Barákars. South of the Gumáni valley the Barákars disappear once more on the western flank of the hills, and only the Dubrájpur beds occur between the traps and the metamorphic rocks; the former recur, however, to the south in the Bansloi valley (Pachwára Pass), and here also, as at the Chuparbhita Pass, the Dubrájpur rocks are only found at the western end of the valley and disappear to the eastward, where the traps rest directly upon the Damúdas. Again, south of the Bansloi, the Dubrájpur beds alone appear, about 250 feet thick, beneath Mahuagarhi hill, but only for a few miles, for the Barákar rocks come in again south of the hill, and extend thence southward, with only one break of about 2 miles, to the Bráhmani, the Dubrájpur grits resting upon them throughout. South of the Bráhmani valley only the Dubrájpur beds are met with along the edge of the hills, but as the boundary is a fault, Damúdas mayexist beneath the surface. Both in the Bráhmani valley and in several isolated patches of Damúda rocks within the hill area to the north, as at the Chuparbhita and Pachwára Passes, the Dubrájpur beds disappear to the eastward, and the traps rest upon the Barákars, so that throughout the whole area the former are evidently confined to a narrow strip of country along the western edge of the hill tract. There is clear evidence in the Bráhmani valley and elsewhere that considerable denudation of the Dubrájpur beds took place before the commencement of the volcanic epoch, and there is reason for believing that the disappearance of these beds to the eastward is due to their having been removed before the lava flows commenced.

Rajmahal group.—The following general section of the Rájmahál group occurs in the northern part of the hills. The thicknesses, in the case of the volcanic rocks especially, are mere approximations, the beds varying greatly in this respect :—

		Feet.
1.	Basalt, in flows of varying thickness, about	1,000
2.	Hard quartzose grit	5
3.	Compact basalt	variable.
3.	Soft crystalline basalt	
4.	White shale, hard and fine-grained, with fossil plants and sandstone	30
5.	Basalt, with much olivine	50
6.	White shale	15
7.	Columnar basalt	——
8.	Black carbonaceous shale	2
9.	Columnar basalt	50
10.	Coarse ferruginous sandstone	50
11.	Basalt, generally soft and containing much olivine	——
12.	(a) Pisolitic iron ore	0 6″
	(b) Carbonaceous black shale	10
13.	Basalt, soft, with olivine, about	100

The whole of this section is not exposed anywhere. The separate beds of which it is composed are of unequal distribution, and variable in thickness, and it frequently happens that great changes in the development of the different beds, both volcanic and sedimentary, take place in the course of a few miles. The only sedimentary formations which have an extensive distribution are the white shales Nos. 4 and 6, but even these are often very poorly seen south of the Bráhmani River, where they appear to rest directly upon the Dubrájpur grits, and to be inferior to all the basalt flows. It is from these white shales that all or nearly all the rich fossil flora of the Rájmahál group has been obtained. The principal fossil localities are in the northern portion of the hills.[1]

The trap rocks are all dark-coloured dolerites; they vary in character from a fine-grained, very tough and hard rock (anamesite), ringing under the hammer, and with the edges of its fracture almost as sharp as those of a quartzite, to a comparatively soft coarsely crystalline basalt. The latter usually contains olivine in large quantities. Many of the trap rocks are amygdaloidal, the enclosed nodules usually containing some form of quartz, either agate, chalcedony, or rock crystal. Occasionally, but less frequently, zeolites are found, stilbite being the commonest, natrolite less abundant; analcime has also been detected. It is not usual to find the cavities lined with green earth, as is so frequently the case amongst the amygdaloids of the Deccan series. The basaltic flows above the sedimentary bands are, as a rule, compact; the most amygdaloidal traps are Nos. 5 and 7 of the section.

Very little light is thrown on the source of the basaltic rocks by any observations within the Rájmahál area. Dykes are rare, and there is only one instance known of an intrusive mass which may mark the site of an old volcanic outburst. This is about 22 miles south-south-east of Colgong on the Ganges, close to a place called Simra, where a group of small conical hills occurs, composed of pinkish trachyte, porphyritic in places, and surrounded by Damúda rocks. The surface of the ground is much obscured by superficial deposits, but there appears good reason for supposing that the core of a volcanic vent is here exposed. It appears not an unfrequent occurrence that the later outbursts from a volcano are more silicious and less basic than earlier eruptions, and that a volcanic core, even when the lava-flows have been doleritic, should itself, when exposed by denudation, prove trachytic. This may be due

[1] The most important localities are Bindrabun and Burio, the former a small village situated about 4 miles south-west of Teliagarhi Fort on the Ganges, and 8 or 9 miles south-east of Pir Pynti station on the East Indian Railway; the latter a large village in the Morel valley.

to the solution of the highly silicious metamorphic rocks, through which the outburst took place, by the molten lava remaining in the fissure after the eruption, and the consequent conversion of that lava from a basic into an acid rock.

Reference has already been made to the evidence in favour of supposing that the trap dykes and intrusions in the fields of the Damúda valley are of Rájmahál age, and both dykes and cores of basalt are common in the portion of Birbhúm lying south-west of the Rájmahál hills. It is possible that the principal vents lay in this direction, or they may have been in the region now covered by the Ganges alluvium. The difficulty of determining the original source of eruptive rocks will be again illustrated in the case of the Deccan traps.

II.—Birbhúm, Deogarh, and Karharbári region.—All the Gondwána basins comprised in this group are of small size, and only lower Gondwána beds are found in them. They serve to connect the Rájmahál outcrops with those of the Damúda valley, and appear to indicate that the lower Gondwána beds once extended over a great part of Western Birbhúm and Northern Hazáribágh. For convenience sake they may be divided into two sections, eastern and western.

A.—Small basins of Birbhum, Deogarh, etc.—Scattered over the metamorphic country west of the Rájmahál hills and north of the Damúda valley, there are several small basins, principally composed of Tálchir beds, but occasionally containing Barákars also. They are of small geological importance and of no economical value, and they require but brief notice.[1]

1. **Tangsuli.**—About 6 miles south-west of the spot where the Dubrájpur beds and the traps of the Rájmahál area disappear beneath the alluvium north of Mahammad Bazar, and between 5 and 6 miles north-west of the civil station of Soory, the principal town in Birbhúm, there is a small tract of Barákar rocks about 2 miles long from north-west to south-east and a mile broad. The beds exposed are sandstones, grits and conglomerates, with some carbonaceous shales containing thin seams of coal of no economical value. The beds form apparently a small basin-shaped synclinal.

The only interesting point about this field is the absence of Tálchir beds. In this respect it differs from all the other Birbhúm fields. It is intermediate in position between the Rániganj coal-field, which commences nearly 20 miles away to the south-west, and the Rájmahál area,

[1] Of the greater number of these outliers no account has ever been published. It is consequently necessary to give a few details as to the position of each. The same remarks apply to the small basins in Hazáribágh, most of which were mapped several years ago by Mr. W. L. Willson.

and it is worthy of notice that throughout the north-eastern portion of the Ràniganj field the Tálchir formation is absent, as in the Tangsúli basin, and the Barákars rest directly on metamorphic rocks, whilst in the Rájmahál area the Tálchirs, as has been already pointed out, are poorly represented, and are, as a rule, wanting. The Tangsúli basin should perhaps be classed in the same group as the coal-fields of the Rájmahál hills.

2. The next exposure of Gondwána rocks occurs about 13 miles west by north of the last. On the Sidh Nadi, about 6 miles west of its junction with the Mor, there is a small tract of sedimentary rocks about 4 miles from east to west and 1½ from north to south. It lies about 6 miles north-east of the town of Kandit, and consists entirely of Tálchirs. The southern boundary is a fault.

3. On the same stream, the Sidh, about 6 miles south-west of the last-named patch and 5 miles west-north-west of Kandit, is a very small basin of Tálchir rocks, about a mile in length from north-west to south-east, and less than half a mile broad. This basin is a simple synclinal.

4. **Kandit Karayah field.**[1]—This commences 4 miles north-west of the last; it is about 4 miles in extreme length from north-west to south-east, and rather more than a mile broad. Both Tálchirs and Damúdas are found, and the latter contain one or two very thin seams of coal, the thickest only measuring 14 inches. The greater portion of the field consists of Tálchir rocks. The beds have throughout a dip to the south-west, and are cut off in that direction by a fault extending the whole length of the field.

All the preceding fields are in Birbhúm; those next mentioned are in Saruth Deogarh, part of the Santhál Parganahs.

5. **Sahajori field.**—The next tract of Gondwána rocks commences within a mile and a half to the north-west of the last. It is much larger, being nearly 10 miles in extreme length from north-west to south-east, by about 2 miles broad where widest, and it covers an area of 11 square miles, of which 5 are occupied by Barákar rocks and the remainder by Tálchirs. The Barákars, which are about 400 feet thick, consist of the usual felspathic sandstones, grits, conglomerates and shales, with a few very thin seams of shaly coal. The Tálchirs are much thicker. The boundaries of the area are for the most part natural; a fault traverses the field from north-west to south-east, and there are a few other faults of smaller importance. The Barákars completely overlap the Tálchirs and rest upon the gneiss at the south-west margin of the area.

[1] For a more detailed account of this and the two following tracts by Mr. Hughes, see Mem. G. S. I., VII, pp. (247)-(255).

6, 7, 8, 9. On the Adjai river, which runs from north to south between the last-described tract and the Karaun or Jainti field, there is a patch of sedimentary beds about 3 miles long by a mile broad. Another little patch, only about a mile in length, comes in west of the river and north-west of the larger tract, and a third equally small is seen in the river, 3 or 4 miles north of the exposure first named. About 3 miles further south are two more patches just west of the river, and about half a mile apart, each about a mile long from north to south, but less than half a mile broad. All these little outliers are of Tálchir beds.

10. **Jainti or Karaun field.**—This is the largest of the small basins of Gondwána beds in the Deogarh and Birbhúm area; it commences about 3 miles west of the Sahajori field, and is about 16 to 17 miles in extreme length, but nowhere much more than 2 miles broad, and it is of peculiar shape, the greater portion of the field being a narrow band running west by north to east by south, with an extension for several miles to the southward from the eastern extremity. The area comprised is 24 square miles, of which only 5 consist of Barákar rocks, the remainder being Tálchir. This field lies west of the Adjai river, rather more than 20 miles south of Deogarh, and the southern extremity lies about 6 miles north of the town of Jamtarra. The Jainti area is traversed by the chord line of the East Indian Railway.

The relative positions of the Tálchirs and Barákars in this field differ from those observed in the Sahajori and Kandit Karayah basins in one important point. In both the other areas the general dip of the beds is south-west, and the fields are more or less cut off by faults along their south-west boundary. In the Jainti or Karaun field there is certainly a fault along the extreme southern boundary of the portion which extends south from Karaun, but the main area lying north of Karaun rests upon the gneiss to the south and dips northward, the northern boundary consisting in great part of a fault running a little north of west. This fault is therefore parallel to the great fault boundaries of the Damúda valley, though the throw is in the reverse direction.

The Barákars are in two separate patches along the northern boundary, the eastern being much the larger of these patches. Some thin seams of inferior coal have been found in them. The Tálchirs, both in this and in the Sahajori field, are well developed, and boulders of great size occur in many places amongst them. These boulders comprise, besides granitic and gneissic rocks, quartzites apparently derived from the rocks of the Khárgpúr (Kurrukpoor) hills distant about 60 miles to the north by west near Monghyr. Concretions of impure argillaceous

limestone are not uncommon in portions of the Tálchirs, and a few fossil plants have been found in these concretions.

11. A small basin of Tálchir rocks, 4½ miles long and about a mile broad, occurs on the Patro Nadi, 14 miles south-west of Deogarh, and 11 north of the extreme western end of the Jainti field.

B.—Small basins of North-Eastern Hazaribagh, including Karharbari.—This group of basins is merely a continuation of the last to the westward, and it comprises in the same way a number of small detached tracts, chiefly consisting of Tálchir rocks and dispersed over the surface of the metamorphic country. Only one is of much economic importance. It may be mentioned here that no basins have been found in the northernmost portion of the Hazáribágh district, and only one extends for a very short distance into any part of Monghyr.

12. A second patch of rock on the Patro Nadi, about 3 miles west of that last mentioned, and situated partly in Parganah Kharagdiha of Hazáribágh, partly in Parganah Chakai belonging to Monghyr. It consists entirely of Tálchirs, and covers less than a square mile of ground.

13. A small tract of Tálchirs, barely a mile long, on the Jaintí Nadi, 11 miles south by east of the last, and 4 miles west of the extreme end of the Jaintí field.

14. An irregularly-shaped area, 6 miles south of the last, and a short distance north of the Barákar River, about 6 miles long from north to south, and varying from a mile to 3 miles broad. It is close to the villages of Deopúr and Ehalapúr.

15. A long basin extending for more than 10 miles along the Barákar river, where this stream forms the boundary between the districts of Hazáribágh and Manbhúm. The western edge of this basin is between 5 and 6 miles south of the Karharbári coal-field. All the four basins hitherto mentioned contain only Tálchirs.

16. **Karharbari (Kurhurbalee) coal-field.**[1]—This small field has attracted great attention, in consequence of the superior quality of the coal found in it. It lies 17 miles south-south-east of the town of Kharagdiha, 16 miles north-east of the high hill of Pareshnáth, close to the Grand Trunk Road, about 15 miles west of the Jainti field and about 23 miles due north of the Jharia coal-field in the Damúda valley. It is 6½ miles in extreme length from west-north-west to east-south-east, and about 2¼ miles broad, and it comprises 11 square miles, of which 8 consist of Karharbári rocks, and the remainder of Tálchirs, with some inliers of the metamorphic formations. The elevation of the plain, composing the greater portion of the field, above the sea, is about 900 to 1,000 feet.

[1] For a description of this coal-field by Mr. Hughes, see Mem. G. S. I., VII, pp. (209)-(246). Some additions have been made from MS. notes.

The northern and southern boundaries of the field are faulted in parts, and nearly straight, running in each case about west-north-west to east-south-east. The throw, however, is very small, that of the south boundary not exceeding 100 feet, and in places, along this boundary, the sedimentary beds are found south of the fault. The field is traversed from west-north-west to east-south-east by other faults, the most important of which appears to form the southern boundary of a large gneiss inlier on which stands the village of Karharbári, and then, running along the northern base of Bhadwa hill, to split into several minor faults to the eastward. Independently of the faults the beds dip generally from all the boundaries towards the middle of the field. Except in the neighbourhood of the northern and southern faults, the rocks are, as a rule, very little disturbed.

The rocks found in this basin consist chiefly of the Karharbári group, already described in the fifth chapter, and Tálchirs. Some conglomerates of small quartz pebbles, which occur in the south-eastern part of the field and extend thence to Lumki or Kamaljor and Bhadwa hills, probably belong to the Barákar group, the chief evidence in favour of separating these conglomerates from the Karharbári group being that they appear to be slightly unconformable to the underlying rocks, and that in some shales, associated with a seam of coal on the hills mentioned, *Schizoneura gondwanensis*, a *Sphenopteris* common to the Barákars, and some other plants occur, not hitherto found in the underlying Karharbári group, whilst the typical Karharbári fossils appear to be wanting. With the exception of this probable outlier of the Barákar group, no representative of any portion of the Damúda series or of any later sedimentary formation is found in the Karharbári field.

The Tálchirs extend throughout the whole of the western boundary and the greater part of the eastern. They are, however, overlapped by the Karharbári group on the eastern boundary near Buriadih, and have not been traced on the south-eastern corner of the field. The village of Karharbári in the western part of the field stands upon a large metamorphic inlier, $1\frac{5}{8}$ miles long from west-north-west to east-north-east. This inlier is surrounded by Tálchir beds except to the south, where the Karharbári beds are brought against the crystalline rocks, apparently by a fault.

The whole thickness of the Tálchirs in this field, where they are best developed, is about 600 feet, and they consist of the usual shales and fine sandstones, the former containing boulders in places. The Karharbári beds are about 500 feet thick, and comprise white and grey felspathic sandstones with grits, conglomeratic beds, shales, and three or four coal seams.

The quality of some of the coal seams is equal, if not superior, to that of the best coals found in the Ránigani field, and is very little, if at all,

inferior to that of good English steam coal. The principal coal seam, which is close to the bottom of the Karharbári group, is from 12 to 16 feet in thickness. The other seams are thinner, not exceeding 7 or 8 feet. All furnish good coal, the best being that from the lower or main seam.

Dykes of volcanic rock are numerous, and some of them seriously injure the coal seams with which they are in contact. Their directions vary.

The Karharbári coal-field, despite its small size, is economically of far greater importance at present than most of the larger fields, as from it is derived the main coal supply for the East Indian Railway.

17. A basin of irregular shape, consisting entirely of Tálchir rocks, traversed in parts by the Barákar river, about 4 miles south-west of the Karharbári field. It is about 7 miles in extreme length from west-north-west to east-south-east, but very narrow, nowhere much exceeding a mile in breadth.

18, 19. Two small patches of Tálchir rocks exposed on the banks of the Barákar above the last. The first is about 2 miles distant from No. 17, and is nearly 2 miles long; the second is half a mile further, and occupies less than a quarter of a square mile.

20. The next three basins are also entirely composed of Tálchir rocks; they lie north-west of Kharagdiha, close to the upper part of the Sakri river, which runs to the north into the Ganges. The first is about 18 miles north of that last specified and 8 miles west by north of Kharagdiha. It is only about 1¾ mile long from north-west to south-east, and rather less than a mile broad.

21. Another tract, 3½ miles north of the last, is scarcely larger.

22. The third of these outlying areas of Tálchir rocks lies close to the large village of Bhandári. It is chiefly north of the Sakri river, but is intersected by the stream in its south-western corner. It measures about 3½ miles from east to west and 2½ from north to south. To the north-east is a detached portion, just separated by the intervening metamorphics.

23. Further down the Sakri, some 8 miles north-west of Bhandári, and about a mile south of the village of Gowan, conglomerates, which have been referred to the Tálchirs, are seen in the banks of a tributary stream. They occupy a very small area, not more than a few hundred yards in length. Five or six miles north-west of this again, near the villages of Deothan and Pihira, two other small outcrops are seen, one north, the other south, of an alluvial valley watered by streams running into the Sakri.

Scarcely any of these small tracts of Gondwána rocks are of sufficient size to enable them to be represented on the general map published herewith.

CHAPTER VIII.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued.* DETAILS OF COAL-FIELDS, ETC.

III, DAMÚDA VALLEY REGION — A, Damúda valley coal-fields — 1, Ránigani (Raneegunge) — 2, Jharia (Jherria) — 3, Bokaro — 4, Rámgarh — 5, South Káranpúra — 6, Káranpúra — B, Coal-fields of Northern Hazáribágh, Southern Behar, and Palámaun (Palamow) — 7, Chopé — 8, Itkúri — 9, Daltonganj — 10, Unsurveyed basins in Palámaun and Lohárdagga — 11, Morhar river south-west of Shergotty.

THE coal-fields of the Damúda valley form a chain of Gondwána basins running east and west, and separated from each other by very short distances. The eastern fields are in the comparatively open and undulating country near the border of the Gangetic alluvial plain, but the western fields are situated in a trough-shaped depression, between the plateaus of Hazáribágh and Chutia Nágpúr (Chota Nagpore), both of which rise to a height of more than 1,000 feet above the level of the Damúda river.

The Damúda valley lies south of the tract in Birbhúm and northern Hazáribágh, over which the basins described in the last chapter are distributed, the area of the two regions being close together to the eastward, but separated to the westward by the Hazáribágh plateau, on which no Gondwána rocks are found, with the exception of one small outlier. The small basins near Hazáribágh and Daltonganj are classed with the present group: they shew the passage to the more extensive areas of the Son (Soane) valley.

The Gondwána basins described in the present section are the following:—

A. Damúda valley—

1. Ránigani.
2. Jharia.
3. Bokáro.
4. Rámgarh.
5. South Káranpúra.
6. Káranpúra.

B. Northern Hazáribágh and Southern Behar—

7. Chopé.
8. Itkúri.
9. Daltonganj.
10. Unsurveyed basins in Palámaun (Palamow) and Lohárdagga.
11. Morhar river near Shergotty.

M

A.—Damuda valley coal-fields.—1. Raniganj (Raneegunge).— The Rániganj, formerly known as the Burdwan, coal-field,[1] from the district in which a portion of its area is comprised, lies in the valley of the river Damúda, which traverses the field from west to east. The town of Ránigani is 106 miles north-west of Calcutta, and the northern extremity of the coal-field is about 25 miles south-west of the southern end of the Rájmahál area. The extent of the known tract occupied by the Gondwána series near Ránigani is about 500 square miles, the field being about 39 miles from east to west, and 18 from north to south; but there is no doubt that the rocks of the coal-field extend farther to the east under the laterite and alluvium which conceal the surface. In this direction the Damúda rocks and their associates, together with the underlying metamorphic formations, disappear completely beneath the thick alluvial deposits of the Ganges valley, which extend for about 300 miles to the eastward. The Barákar river, flowing from the north-west, joins the Damúda in the western part of the Ránigani coal-field, whilst the northern portion of the field is traversed and drained by the river Adjai.

The Ránigani field has been known for a long time, and its geology has received attention for the last 30 or 40 years. It has thus furnished the typical sections of the rocks, sections with which all those found in other parts of India have been compared. So far as the lower Gondwána formations are concerned, the sequence is more full, and the different sub-divisions are better represented, in the Ránigani area, than in any other in Eastern India, and the only tract which can compare with it in interest is that exposed in the Sátpúra hills south of the Narbada valley. The latter, however, has been far less carefully surveyed; the country is wild and covered with jungle, and the Damúda beds greatly concealed by rocks of the upper Gondwána series and by the Deccan trap; moreover, the amount of investigation for commercial purposes by boring, mining, &c., is very large in the Ránigani coal-field; very small, and confined to a limited area, in the Sátpúra basin.

The rocks are, on the whole, fairly exposed in the Ránigani coal-field, although the lower sub-divisions—the Tálchirs, Barákars, and ironstone shales,[1] as is usually the case amongst the Gondwána rocks—are much better seen than the higher, owing partly to the former existing in parts of the area in which there is less alluvial covering, partly to the greater tendency of the latter to decompose into a sandy clay which conceals the surface. There is, however, no question that much might now be added to the knowledge of the geology and palæontology of the field by

[1] A full account of this coal-field is given in Mem. G. S. I., III, pp. 1-195.

a fresh survey; because, since the year 1860, when the country was last examined geologically, the number of collieries, in the upper beds or Rániganj group especially, has largely increased, and the presence of seams of coal has been ascertained by boring in places where none were previously known to exist.

The rocks found in the Ráníganj coal-field, and their approximate vertical extent where thickest, are the following:—

	Feet.
1. Mahádeva? (? Dubrájpur)	500
2. Panchet	1,500
3. Damúda—	
A. Ráníganj	5,000
B. Ironstone shales	1,400
C. Barákar	2,000
4. Tálchir	800
	11,200

The general dip is approximately from north to south, the lowest beds being exposed along the northern border of the field. The southern dip is, on the whole, wonderfully persistent. In the northern portion of the area it is low, usually about 5°, and rarely exceeding 10°, but towards the southern edge of the field there are great rolls of the strata, and, frequently, high dips. Finally, at the southern edge the whole of the Gondwána series are turned up at high angles, then cut off abruptly, and metamorphic rocks come to the surface. Whether this abrupt termination is due to faulting or to the rocks having originally been deposited against a cliff is a disputed point.[1]

Independently of this boundary there are several large faults in the field, of some of which no trace is seen on the surface, but they are revealed, as is so frequently the case, by mining. Along the northern boundary several nearly parallel faults, with a general north-west south-east direction, throw the rocks in succession, each having a downthrow to the north-east. One patch of Barákars thrown by the fault farthest to the north-east is quite unconnected with the field. Another fault runs for some miles almost down the bed of the Adjai river, and throws down, on its north side, the tract of Barákar beds containing the coal near Kásta.

[1] See pp. 103-106. That some faulting has taken place along this line is almost certain; it is impossible otherwise to account for the disturbance and crushing in the Gondwána beds immediately to the northward. Still the original estimate of the extent to which the rocks are thrown may be excessive, and the line of boundary may be approximately the original limit of the rocks. It is only right to say that all the surveyors who mapped the Ráníganj and the other Damúda fields are still disposed to consider these boundaries as faulted.

In the west of the field one important fault runs nearly north and south down the bed of the Barákar river: another running north-west and south-east forms the south-west boundary of the field for about 14 miles. This last fault is parallel to the faults on the northern boundary already mentioned, and the throw is in the same direction.

The Tálchirs are only found in the north-western portion of the field. They pass up into the Barákars north of Táldánga, a little west of the Barákar river, and at this locality they attain their greatest thickness, their upper portion consisting of coarse sandstones and conglomerates, with only occasional bands of the characteristic fine silty beds of which their lower portion is entirely composed. Proceeding either east or west from the locality named, the upper beds of the Tálchir group disappear, and although the thickness is but little less to the west, to the east it gradually diminishes as the Damúdas overlap bed after bed until the Tálchirs disappear completely. They are last seen in the Adjai river about 22 miles from the western extremity of the fieeld and thence to the eastward the Barákars rest on metamorphic rocks.

Boulders are not so commonly associated with the Tálchir rocks in the. Rániganj coal-field as in some other areas. They are numerous, however, in the western extremity of the field.

No representatives of the Karharbári group have hitherto been detected in the Rániganj field or in the other basins of the Damúda valley, but it is highly probable that, amongst the passage beds hitherto classed with the uppermost Tálchirs or the bottom beds of the Barákars, Karharbári beds may have been included.

The greater portion of the basin consists of Damúda rocks, and the higher group, that of Rániganj, is not only very fully developed in this area, but it is rich in coal seams. Many of these seams are of considerable thickness, some of them even amounting to 20 feet. In this respect, however, they are exceeded by the Barákar seams, one of which at Kásta, in the northern part of the field beyond the Adjai river, is from 33 to 35 feet thick. The Barákar seams in the Rániganj area, as a rule, are of inferior quality to those found in the Rániganj group: there are exceptions, however, some excellent coal being found in a Barákar seam near Chánch, west of the Barákar river, and also at Benodakatta, east of the Barákar. One great cause of the inferiority in the Barákar seams is the prevalence of basalt running in strings through the coal and converting it into a worthless shaly mineral.[1] This is a very rare occurrence in the higher group, and it is very singular,

[1] Some of this altered coal exhibits columnar structure very finely, the hexagonal prisms formed being 2 or 3 inches in diameter.

because both groups are traversed equally by numerous basaltic dykes, some of them of large size. One of these dykes runs for 20 miles through the coal measures. The small dykes, which permeate the Barákar coal seams, may belong to an older series than the other dykes of the field, and may possibly have existed before the deposition of the Ráníganj group. Some of the Barákar coal exhibits a peculiar spheroidal structure, and round balls of various sizes, up to more than a foot in diameter, break away from the mass when the coal is mined. So thoroughly are these rounded that they were taken at first for rolled fragments derived from some older formation.[1]

The proportion of coal in the lower Damúda beds is at times large. In one of the best sections exposed in the west of the field—that seen in the Kúdia and Pasai streams—an aggregate amount of 175 feet of coal is exposed in a total thickness of 833 feet of rock, so that upwards of one-fifth of the whole is coal. A large portion of this enormous thickness, however, consists of inferior coal and shale not worth extraction, and some seams are injured by intrusive trap, but a considerable quantity of useful fuel could be obtained at this spot, though it is an exception to find any seam continuing unchanged throughout a large area. So irregular are the Barákar seams in thickness, that beds several feet thick are sometimes seen to thin out and disappear entirely within a few yards. This is especially the case when the roof of the coal consists of coarse sandstone, and in such cases there is evidence that, through some change in the circumstances of deposition, the coal has been swept away and sand has accumulated in its place. There is also, amongst the other Barákar beds of the Ráníganj coal-field, a great tendency to vary in quality within short distances.

The ironstone shales, which overlie the Barákars, form a marked ridge of raised ground traversing the coal-field from east to west, their elevation above the other rocks being due, not to their hardness, but to their power of resisting disintegration. They thin out and are overlapped by the Ráníganj group in the south-west corner of the field, where their relations to the underlying Barákars are peculiar, and it is not clear whether the latter have been upheaved and denuded before the ironstone shales were deposited, or whether this spot has been the original margin of deposition of both groups.

Clay ironstone, both of the ordinary non-carbonaceous form, and also of the carbonaceous variety known as "black band," is found in considerable quantities interstratified with the shales. Ironstone nodules

[1] See J. A. S. B., XVII, Pt. 1, p. 59; XVIII, p. 412; XIX, p. 75; and Mem. G. S. I., III, p. 66.

also occur. The seams of clay iron ore vary in thickness from 2 inches to a foot, and occur at irregular intervals. The proportion which the ironstone-bands bear to the shales varies: in one measured section of 150 feet of shale, 26 bands of iron ore were met with, the aggregate thickness of which was about 8½ feet, or 1 in 17½; whilst in a pit sunk to a depth of 52 feet at Bádúl, the proportion was 1 in 9, but three quarters of the iron ore in this case was black band, which contains less iron. The shales appear in some places at all events quite impermeable to water—an important advantage in mining.

As has already been stated, the coals of the Ráníganj group are in many cases of superior quality to those of the Barákar group found in this coal-field. The Ráníganj seams are, moreover, constant in thickness and quality over larger areas than the Barákar seams, and the former are only known in a very few cases to have been seriously injured by volcanic rocks, the basalt dykes which traverse the rocks, as a rule, affecting only the coal in immediate contact, and not ramifying in strings through the coal seams. The proportion of coal to the whole thickness of beds is, however, very much less in the Ráníganj group.

The rich seams of Ráníganj itself are situated in ground so much covered with laterite and alluvial deposits that the relations of the beds are very difficult to trace. The strata associated with the coals appear, however, to be some of the highest of the group, and it is possible that these beds have elsewhere been removed by denudation before the deposition of the Panchet formation. At the same time this is by no means proved, and it is equally possible that the Ráníganj coal-beds represent some of the seams found farther west about Chinakúri. The seams of Sitarámpur and Sánktoria, in the neighbourhood of Chinakúri, are on a much lower horizon than those of the Ráníganj neighbourhood, and the coal is of superior quality, one bed yielding a good coking coal, which has of late been employed successfully in the manufacture of iron.

A band of ironstone in the upper portion of the Ráníganj group affords great assistance in tracing out the relations of this group to the overlying Panchets, for the ironstone band can be traced, by the fragments found on the surface, over a large area, in which none of the other-associated beds can be recognised with certainty. Here and there sections of the band are seen in streams, and some carbonaceous shales with intercalated seams of clay iron-ore are exposed, the mineral character being precisely the same as that of the thicker ironstone shales below. The ironstone band is found, at a maximum depth of 700 to 900 feet below the base of the Panchet group, throughout a large area in the western and southern portion of the field, but it is completely overlapped by

Panchet beds a few miles west of Asansol on the Grand Trunk Road. It reappears further east, but it cannot be traced in the neighbourhood of Ráníganj for want of sections.

In the south-western portion of the coal-field a bed of magnesian limestone has been found in the lower portion of the Ráníganj group,[1] and has been quarried to some extent, in the ground north-west of Panchet hill, for a supply of flux to the iron-works and also for burning into lime. The calcareous band comprises two beds near Bághmára, under Panchet hill, the upper bed being too impure and sandy for use, whilst the lower, which contains 63 per cent. of carbonate of lime, 14 per cent. of carbonate of magnesia, and 20 per cent. of sand and clay, is about 12 feet thick. The limestone has been traced over a considerable area to the north-eastward; becoming, however, more sandy and impure, and apparently dividing into smaller bands intercalated with sandstone at a distance from the original locality. Calcareous sandstones are common in the Ráníganj group; this, however, is the only bed which has hitherto proved sufficiently rich in lime to be worth quarrying.

The Ráníganj group occupies a very large area, nearly half of the field being composed of it. The tract covered by the higher formations is comparatively small. The Panchets occupy a basin about 8 miles across in the middle of the coal-field, and extend to the southern margin; they are also found in two smaller areas along the southern edge of the field; one of these areas surrounds Panchet hill, the highest and largest hill in the coal-field, on all sides except the south.

The change to the Panchet beds is usually marked by the occurrence of red clay on the surface of the ground. The felspar, which forms a considerable proportion of the sandstones of the Panchet group, remains undecomposed instead of being converted into kaolin as in the Damúdas: the sandstones of the former group are consequently more fusible, and the bands of hard semi-fused rocks, on each side of the basaltic dykes traversing the beds, stand out like walls in places near the Damúda river. The Panchets are extremely micaceous throughout.

The bed containing the reptilian remains mentioned in the general description of the Panchet group[2] is best exposed in the bed of the Damúda near the village of Deoli,[3] about a quarter of a mile east of the mouth of the Besram stream, and close to the right (south) bank of the river. The same bed is seen in some other places on the river bank and it was traced by Mr. Tween, who collected most of the bones, over

[1] Mallet, Rec. G. S. I., X, p. 148.

[2] *Ante*, p. 133.

[3] This was the case in 1860; a change may have taken place subsequently in the river channel.

a considerable tract of country near the middle of the synclinal basin occupied by the Panchets.

Along the southern border of the field is a line of hills, Panchet, Garangi, Beharináth, and some smaller rises south of Rániganj, the upper portions of which are composed of coarse ferruginous grits and conglomerates, quite distinct from any beds found in other parts of the field. These rocks were at first supposed to be an upper subdivision of the Panchets, but it appears more probable, now that we have a better knowledge of the rocks intervening between the Damúda and Narbada valleys, that these coarse conglomerates represent a portion of the Mahádeva formation. There is also, as already mentioned, a probability that the grits and conglomerates may represent those underlying the traps of the Rájmahál hills. No fossils have hitherto been found in the Rániganj field to aid in determining the age of the upper beds.

The relations of these grits to the underlying Panchets are extremely obscure, the hill sides on which the junction takes place being greatly concealed by pebbles and detritus from the upper beds. There is some appearance of, the grits overlapping the lower beds and resting on the metamorphics. If this be the case it may also be found that the lower formations alone are faulted against the metamorphics.

In the eastern portion of the Rániganj field a ridge of high land, running north and south, about 16 miles east of Rániganj, consists of coarse yellow and white felspathic grit, with beds of white, bluish-grey, and mottled clay, and thin bands of hard quartzose ferruginous grit. These rocks are best seen in a railway cutting near Kálipúr. They stretch from Khyrasol, 17 miles east-south-east of Rániganj, to the Adjai river, and similar beds are found to the northward near Soory and to the southward in Bankúra (Bancoora) and Midnapur (Midnapore). It appears possible that they do not belong to the Gondwána series at all. At the same time there is an equal possibility of their being of Rájmahál age, but no fossils have hitherto been detected in them.

The basaltic dykes of the field have already been mentioned. They are numerous, and although their direction varies greatly, a very large number run nearly north-west and south-east. This, as has already been noticed, is the direction of some of the most important faults in the field; but the dykes are clearly of later age than the faults, not a single instance being known, except in the case of the horizontal intrusions amongst the Barákar coal-seams, of a dyke being thrown by a fault, although there are a few cases in which a dyke runs along a fault. The apparent dislocation of the horizontal dykes in the

Barákar coal seams may be due to the intrusions following the direction of the coal, and not to the dykes being prior in age to the faults. The traps traverse all the rocks in the field except the Mahádevas: the latter occupy so small an area that it is impossible to feel assured that they are newer than the dykes, but still the absence of any volcanic intrusions amongst them is not confined to the Ránigan̤j field. There are many dykes in the Panchet beds. At the same time, if the dykes are of older date than the Mahádevas, it is evident that the suggestion made above, that the Ránigan̤j field and other portions of the Damúda valley were once covered by Rájmahál traps of the same age as the dykes, becomes untenable, because those traps would have been intercalated between the Panchets and Mahádevas.

Besides the dykes, some of which are of great length and breadth, some irregular basaltic intrusions are found in the eastern part of the field, and these become more numerous and larger to the northward, in the country between the Ránigan̤j field and the Rájmahál hills. All the evidence tends to connect the dykes with the volcanic outbursts which produced the basaltic traps of the Rájmahâls, and to prove that all the disturbances which affected the Damúda and Panchet groups preceded the Rájmahál epoch of volcanic action. It may as well be noted here that all the facts observed in connexion with the dykes of the other Damúda fields lying west and north-west of Ránigan̤j lead to precisely the same conclusions with regard to the age of the dykes and their relation to the different groups.

The question of the possible extension of this coal-field to the eastward is one of considerable geological and economical interest. Coal has been found by boring several miles within the alluvial area, and the circumstance that fragments of coal were found at a depth of 390 feet in a boring for water at Calcutta renders it possible that Damúda beds may exist in other places beneath the alluvial plain of the Ganges delta.

2. Jharia (Jherria).—The Jharia coal-field[1] commences at a distance of 16 miles west of the south-western extremity of the Ránigan̤j coal-field, whilst the north-east edge of the former and the western extremity of the latter are but 13 miles apart. The Jharia field is inferior to the Ránigan̤j in size, being about 26 miles in extreme length from west by north to east by south, and nowhere more than 10 miles broad. It comprises an area of about 200 square miles. Like the Ránigan̤j field it is traversed from west to east by the river Damúda, the major portion of the field lying north of the river.

[1] For a full account by Mr. Hughes, see Mem. G. S. I., V, pp. 227–336.

The geology closely corresponds to that of the Ránigani field. The deposits of the Gondwána series are entirely surrounded by metamorphic rocks, and have a general dip towards the south boundary, where they are abruptly cut off by a long nearly straight line which appears to be similar to the same feature in the Ránigani field, though the throw is of less magnitude. No beds are exposed above the Damúdas, the only groups represented being the Tálchirs and the three subdivisions of the Damúda formation. The total thickness of beds exposed amounts to 6,800 feet, consisting of—

	Feet.	Feet.
Damúda—		
Ránigani group	2,200	5,900
Ironstone shales	700	
Barákar group	3,000	
Tálchir		900

The Tálchir group is completely overlapped in the extreme east of the field, and throughout the greater portion of the northern border it occupies but a narrow strip of country, nowhere more than half a mile, and usually less than a quarter of a mile, broad. In the west of the field, however, the Tálchirs occupy a considerable area. They present the usual features, consisting mainly of fine shales which split up into angular and acicular fragments. Some concretionary nodules of limestone are found in them. The boulder bed is well developed in many places.[1]

The Tálchirs in the Jharia coal-field appear to pass upwards into the Barákars as they do locally in the western portion of the Ránigani field, and no distinct unconformity has been observed between the two. The Barákars occupy the greater portion of the field,[2] and are shaly on the whole, with thick felspathic grits and sandstones near their base. Coal is found throughout; the larger seams, however, are chiefly towards the base of the group. The general characters of the coal seams are the same as in the Ránigani field: the quality of the coal is very variable, some seams yielding good fuel, whilst others are little better than shale. Some very thick seams have been noticed, one amounting to as much as 60 feet; but there is precisely the same variation in thickness in the case of each seam as was observed to the eastward. Many seams also, as in the Barákar group of the Ránigani field, are traversed by strings and dykes of basalt in such a manner as to render the coal worthless.

[1] In the detailed account of this field, several carefully-measured descriptive sections of the different formations are given. An excellent section of the Tálchir group will be found l. c., p. 241.

[2] Detailed sections are given in the report, l. c., pp. 261, 266, 274, 280, 285, and especially p. 296.

Despite these drawbacks there is unquestionably a large quantity of very fair coal procurable in the Jharia field.

The ironstone shales do not form nearly so well-marked a group as in the Rániganj field; they are best seen in the middle of the field and are represented towards the west in the Jamúni river by thin argillaceous shales and sandstones. Ironstones are less abundant than in the Rániganj field; their quality is poor, and they are so silicious that the natives are unable to smelt them.

Of the Rániganj group,[1] only the lower beds appear to have been preserved, all the higher portions, if they ever existed, having been removed by denudation. As a natural consequence, the valuable coal seams of Rániganj, Sitarámpur, Chinakúri, &c., all of which are in the higher portions of the Rániganj group, are unrepresented in the Jharia field, and but few coal seams have hitherto been traced in the latter area above the ironstone shales. The rocks of this group, moreover, are greatly disturbed in the Jharia basin, and are in general inclined at an angle which would seriously interfere with mining.

Basaltic dykes are nearly, if not quite, as common as in the Rániganj field, and are in every respect similar to those described as occurring to the eastward.

3. Bokaro.—The River Bokáro, which traverses the basin from west to east before joining the Damúda, has furnished the name for the next coal-field,[2] in the eastern portion of which the two streams unite. The Bokáro tract of Gondwána beds lies to the south-east of the town of Hazáribágh, and, like the Rámghur and Káranpúra fields, occupies the low valley, whilst the ground both north and south is much higher and composed of metamorphic rocks.

The Bokáro coal-field commences only 2 miles west of the extreme western limit of the Jharia field, and extends for 40 miles from east to west. It is narrow, being nowhere more than 6½ miles from north to south, and the area occupied is about 220 square miles. It may be described as occupying in the main a trough-like depression between two parallel faults, one of which forms part of the northern boundary, and the other the greater portion of the southern; but about half of the northern boundary is natural, whilst the southern fault passes for a considerable distance within the field, rocks of the Damúda series being found for some distance to the south of it. These large faults run nearly east and west in this field, but smaller faults with a general north-north-west and south-south-east direction are met with, and probably belong to the

[1] Measured sections in detail are given, l. c., pp. 314, 315, 318, &c.

[2] For a full description by Mr. Hughes, see Mem. G. S. I., VI, pp. (39)–(108).

same system as the north-west and south-east faults of the Ráníganj field. They appear to be of later date than the great east and west faults, which are dislocated in places by the north-west and south-east throws. On the whole, the rocks of the Bokáro area are more disturbed than in the fields to the eastward.

In the middle of the field, about half way between the extreme east and west boundaries, Lúgú (Loogoo) hill rises to a height of 1,500 feet above the valley, and 3,450 feet above the sea, the top being above the general level of the Hazáribágh plateau. This hill consists of Mahádeva rocks.

The formations exposed in this field are the following; the thickness of several of the groups has not been determined:—

Mahádeva (formerly described as Upper Panchets).
Panchets.
Damúda—
  Ráníganj.
  Ironstone shales.
  Barákar.
Tálchir.

The field may be divided into three parts, the two extremities consisting almost entirely of Barákars, the central sub-division, which is the smallest, of the higher beds. The Tálchirs are but poorly developed, their principal exposure being on the western edge of the field. A few small patches are found along the northern border, and the same beds form a narrow margin for about four miles on the north-eastern boundary. They are overlapped in many places by the Barákars, which rest directly upon the metamorphic rocks throughout at least half of that portion of the boundary which does not consist of a fault. The Tálchirs are of the usual character, and the boulder bed is well developed, boulders being found occasionally in the upper members of the group as well as near the base.

The Barákars occupy about three-quarters of the whole field. Their mineral character exhibits no peculiarity; the conglomerate of small quartz pebbles at their base is well marked, and they contain numerous coal seams, some of them of considerable thickness, but the coal is variable in character, and, as a rule, of inferior quality. Still good seams occur, and others may be found by boring. Ironstones occur in the Barákars, and there appears, on the whole, a tendency to a passage from these beds into the overlying ironstone shales.

The ironstone shales are more fully developed in this field than in any other, being 1,500 feet thick, and they present precisely the same character as in the Ráníganj field. They pass downwards into the Barákars, being only distinguished by mineral characters, but there is

well-marked unconformity between them and the Rániganj group, the latter abruptly overlapping the former in places. The ironstone group, besides intervening between the Barákars and the Rániganj beds east of Lúgú hill (both are wanting immediately to the west), occurs in a small tract in the north-west of the field, where both it and the overlying group are let in by faults, and it occupies several tracts in the south-west of the field south of the great fault, which forms a large portion of the southern boundary. A few other patches of ironstone shales occur, but they are small and of no importance. The ironstones themselves are rather silicious and inferior in quality to the bands associated with the Barákar group.

The Rániganj group occupies a tract of about 14 square miles in extent to the east of the Panchet area around Lúgú hill, and is again found near Basatpúr in the north-west corner of the field, resting on the ironstone shales. The mineral character is the same as in the fields to the eastward, but scarcely any useful coal seams have been detected amongst the beds of this group in the Bokáro area.

The Panchets occupy a tract in the middle of the field; Lúgú hill is entirely surrounded by them, and the basal portion of the hill itself composed of them. They consist of the usual micaceous sandstones, green silty beds, and red clays, the latter not in such thick beds as in the Rániganj field. Their unconformity to the Damúdas is more striking in this field than in that of Rániganj, for, although they rest on the Rániganj beds to the eastward, they completely, within the short distance of about a mile, overlap both the Rániganj group and the ironstone shales north of Lúgú hill, and to the west they rest upon the Barákar beds. The mode of overlap is characteristic, and apparently due to the Damúdas having been upheaved and denuded before the Panchets were deposited, the latter, where dipping at an angle of 15°, being seen to rest upon the former, dipping at 25° to 30°. The Mahádevas compose all the upper portion of Lúgú hill, and consist of coarse conglomerates, grits, and sandstone, much impregnated with iron, and having generally a reddish colour; they precisely resemble the beds of Panchet hill in the Rániganj field. As frequently happens in the rocks of the upper Gondwána series, the sides of the hills are so much covered by pebbles and detritus, that it is difficult accurately to ascertain the relations between these beds and those of the underlying group. The rocks of the hill are nearly horizontal.

Basaltic dykes are common in the Bokáro field, but they appear to have no prevailing direction; as usual they traverse all the groups except the Mahádevas. They appear to be of the same age as in the Rániganj field.

4. **Ramgarh.**—The Rámgarh coal-field[1] lies due south of the Bokáro area, the distance between the two where nearest being only 3½ miles. This present field derives its name from the old town of Rámgarh on the Damúda river, near the western extremity of the area, and is of an irregularly triangular form, its greatest length, from east to west, being 14 miles; it is broadest at the eastern extremity, where it measures about 8 miles from north to south, and it diminishes rapidly in breadth to the westward, until it is not more that a mile broad; it, however, continues for between 5 and 6 miles to the west beyond this narrow portion, and exhibits a breadth of from 1 to 2 miles. The whole area is about 40 square miles. The field is traversed throughout its entire length from west to east by the river Damúda.

There is again in this small area a repetition of the peculiar characters remarked in the eastern fields; a general dip of the rocks to the southward, and an abrupt and faulted southern boundary. The direction of the western portion of the boundary is nearly due east and west as in the Bokáro field; in the eastern portion, however, the strike is east-south-east. The western part of the field is much cut up by cross faults running north-north-west and south-south-east; these dislocations, as in the Bokáro field, appear to be of later date than the east and west faults.

No rocks higher than the Rániganj group occur in the Rámgarh field. The groups exposed, with their approximate thickness, are the following:—

Damúda—	
Rániganj group	?
Ironstone shales	1,200
Barákar group	3,000
Tálchir	850—900

The Tálchir rocks occupy a considerable area in the extreme north of the field, and they again occur on the eastern boundary, but they are overlapped by the Damúdas throughout the greater portion of the eastern and northern borders of the Gondwána area, and they only appear in two small patches along the north-western boundary and in another at the extreme western end of the field. In one spot they are found on the southern fault, which traverses them at a place where its throw is very small. The boulder bed is well developed to the north.

The Barákars are the only beds in the field which are developed over a large area, and they present an unusual thickness. They are of the same character as in the neighbouring coal-fields, and consist of grits, sandstones, and shales, with conglomerates of small white quartz pebbles

[1] For a full description by Mr. Ball, see Mem. G. S. I., VI, pp. (109)-(135).

towards the base. Coal seams are numerous; the quality, as a rule, appears inferior, but some good beds occur. No attempt, however, has been made to explore the field by boring and mining.

The ironstone shales are much less carbonaceous than in the Ránigauj field, and consist of argillaceous shales and sandstones, with a few bands of poor clay ironstone. The area occupied by the group does not exceed half a square mile, and, with the exception of a small outlier on the Damúda, due south of Púnú village in the east of the field, the ironstone group is confined to a tract a little east of Rámgarh, where it intervenes between Barákar and Ráníganj beds. This tract, the only portion of the Rámgarh area in which the Ráníganj group is found, is surrounded by faults on all sides. The rocks of Ráníganj age occupy nearly a square mile, but they are much disturbed by faults, and no coal seams have been detected amongst them. Only one basaltic dyke is found in the field.

5. **South Karanpura.**—The two Káranpúra fields conclude the list of the Damúda valley coal basins. They lie due west of the Bokáro and Rámgarh fields, and in close proximity to them, only a mile intervening between the Bokáro and Káranpúra tracts, and about 2½ miles between the field of Rámgarh and that of South Káranpúra. The South Káranpúra is a small portion separated from the main field by a narrow belt of metamorphic country, but as the southern field extends farther to the eastward it may be noticed first.

The South Káranpúra field[1] is 22 miles in length from east to west, its average breadth being 4 miles; its extreme breadth near the eastern extremity 5 miles, and the area occupied 72 square miles, 3 of which, however, are composed of an inlier of metamorphic rocks. The Damúda river traverses the field from east to west.

The southern boundary consists as usual of a fault, which cuts off all the sedimentary rocks, none of them being found on the southern side of the throw; the general dip is, as in the other fields, to the southward. The rocks exposed consist of—

- Mahádeva (formerly described as Upper Panchets).
- Damúda—
  - Ráníganj.
  - Ironstone shales.
  - Barákar.
- Tálchirs.

The Panchets being completely absent, though found both in the Káranpúra field to the northwest and west, and in that of Bokáro to the north-east.

[1] For a full description by Mr. Hughes, see Mem. G. S. I., VII, pp. (322)-(330).

The Tálchirs are very ill-developed. They occupy a little tract, about a mile long and barely half a mile broad, at the eastern extremity of the field, and another very narrow strip, about 2 miles long, on the northern boundary. Elsewhere throughout the northern and eastern boundaries, the Barákar group rests directly upon the metamorphics. No Tálchirs are exposed around the large inlier of gneissic rock in the eastern part of the field, although the boundaries are natural. The Barákar beds occupy nearly three-quarters of the area, and appear to contain more coal than they do in the other fields of the upper Damúda valley; an appearance which may, perhaps, be due to better sections being exposed. Some of the coal is of fair quality, and bands of rich ironstone occur.

The upper Damúda groups are poorly developed, though they cover a larger area than in the Rámgarh field. They occupy a tract along the south boundary, nearer to the western than the eastern extremity, and about 9 miles long, but nowhere more than about 2 broad. The ironstone shales only occur to the eastward. To the west the Ràniganj beds overlap the ironstone shales, and rest on Barákars. Neither of the upper Damúda groups presents any features of interest.

The Mahádevas form two small hills, one of which, called Henjdag, rests upon Ràniganj beds close to the eastern extremity of their area; the other in the extreme west of the field, called Patál hill, is larger, occupying an area of about two square miles, and rests directly upon Barákar rocks. Not a trace of Panchet beds could be detected in either case, yet in both hills there is pseudo-conformity between the Mahádevas and the Damúdas, the rocks being very nearly horizontal. It is clear that in this case there must have been a break in time, represented in the neighbouring coal-fields by the Panchet group, between the period of deposition of the Damúdas and Mahádevas.

6. **Karanpura.**—The names of this and of the preceding field are derived from the parganah in which the greater portion of their surface is comprised. The Káranpúra[1] is second only to the Ràniganj field in extent amongst the basins of the Damúda valley. It commences at a distance of about 10 miles south-west of Hazáribágh; it is 42 miles in extreme length from east to west, and 19 from north to south, and it covers 472 square miles. The Damúda river runs for many miles through the south-western portion of the field; the eastern part of the area is drained by the Hohárú, a tributary of the Damúda.

[1] Described by Mr. Hughes,—see Mem. G. S. I., VII, pp. (285)-(321).

The formations found in the Káranpúra area are the following, with their approximate thickness so far as it has been ascertained :—

Mahádeva (Upper Panchets)	300
Panchets	?
Damúda—	
Ráníganj	?
Ironstone shales	600
Barákar	1,500
Tálchir	400

The form of the area is nearly elliptical, and the field has more of the characters of a basin than any other tract of Gondwána rocks in the Damúda valley. The highest beds occupy the middle of the field, and the lower formations roll up to the south of them. To the eastward the beds are cut off on the south by an east and west fault, which brings up to the surface the belt of metamorphic rocks intervening between this field and that of South Káranpúra. To the westward the field extends much farther to the south than to the eastward, the south-western portion consisting chiefly of Barákar rocks, but higher beds occur in a minor basin-shaped depression near the south-western corner, and the southern boundary appears to be along a continuation to the westward of the line of fault which limits the South Káranpúra field farther east.

In the rocks occupying this field a very important change has taken place in the relations of the different groups to each other. In the Ráníganj coal-field, the Ráníganj group is the most developed, and three groups, all of considerable thickness, intervene between the Mahádevas and the Barákars. All these intermediate groups thin out greatly to the westward, and their diminution in thickness is continued in the present field. Still farther to the west no rocks intervene between the Barákars and a great group of sandstones and conglomerates resembling, in mineral character, the Mahádevas of the Damúda valley and of the Sátpúra hills.

The Tálchirs occupy but a small tract in the Káranpúra coal-field, their whole area being but 9 square miles. They occur on the eastern edge of the field in several places, along the south-eastern boundary north-west of Patál hill in the South Káranpúra field, for about 6 miles, and again in the north-west of the field, where they extend for about 3 miles along the boundary, and run thence for some distance to the north-west up the valley of a small stream. They also surround an inlier of gneissic rock in the south-east of the field. Elsewhere, that is (excluding the faulted boundaries) throughout nineteen-twentieths of the margin of the field, the Barákars rest upon the gneiss. The Tálchirs present

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no peculiarities; they are poorly developed, and consist of the usual shales and fine-grained sandstones with the boulder conglomerate at their base.

The Barákars cover about one-half of the basin, and almost completely surround the area occupied by the higher formations. They are much less shaly, and contain more sandstones than to the eastward; their coal seams appear less numerous, but several may exist which are not exposed at the surface. Roughly, the Barákars of the Káranpúra area may be divided into three sub-groups, the lowest division consisting of conglomerates of small quartz pebbles, coarse sandstones and grits, with some thick coal seams: the middle division contains no conglomerates; it is chiefly composed of sandstones which are less coarse than those below; it has coal seams of moderate thickness, and there are several beds of iron-ore: the upper division is made up chiefly of shales and shaly sandstones, with ironstones at the top, and the coal seams occurring are thin.

As usual, the coarse grits and pebble beds form low hills, and serve to mark out the outcrop of these beds and to distinguish the ground occupied by the lower members of the group from that covered by the higher sub-divisions, the surface of which is usually level like the area occupied by the ironstone shales and Ráníganj group. Some of the felspathic sandstones of the Barákars weather into peculiar little pitted depressions, having a slight resemblance to foot-prints of animals. The relative thickness of different members of this group varies greatly in different parts of the coal-field, the same bed of sandstone being found in places to change in thickness within a short distance.

The principal band of coal is found about 300 feet above the base of the Barákars, and there is a seam of shale and coal, together 30 to 40 feet thick, exposed at this horizon in several parts of the field, and probably constant throughout. In places the thick seam is of even larger dimensions than those above given; in one section it measures 77 feet. In this respect, as in several others, there is an approximation in this field to the conditions existing in the Gondwána areas of the Central Provinces. The quality of the coal seam is variable, and a large portion of its thickness is mere shale. Some rich ironstones are also found in the Barákar group; the best are hæmatites, containing as much as 60 per cent of iron.

The ironstone shales are found in the northern and north-eastern portions of the field, where they form a belt, rarely exceeding half a mile in breadth, along the edge of the area occupied by the Ráníganj group. To the west and south they are completely overlapped everywhere, but they occur around a small area of Ráníganj beds close to the southern boundary, near the eastern extremity of the field. The shales are paler

in colour, more silicious and much less carbonaceous than they are in the Rániganj field. The ironstones too appear to be somewhat less rich.

The Ránigaṇj group forms, in the first place, a band about 2 to 3 miles broad on the average, surrounding the Panchet and Mahádeva area in the middle of the field; and, secondly, a much narrower belt in the little south-western basin around Gerwa hill. Ránigaṇj beds are also found in the south-east, near Chano, where they occupy a small area against the southern boundary faults. There is but little in their mineral character to distinguish them from the upper portion of the Barákar group, and where, as in the western part of this field, the intervening ironstone shales are absent, it is very difficult to draw a line between the two remaining groups of the Damúda series. Several seams of coal are found in the Ránigaṇj beds of the Káranpúra field, but the majority are thin, only a few being of sufficient thickness to be worth working. In one spot a gneiss inlier appears in the middle of the Ránigaṇj beds, and is supposed by Mr. Hughes, who mapped the field, to be an old peak which stood up in the middle of the area on which the rocks of the Gondwána series were deposited. This is not improbable, as the surface on which these rocks rest is very uneven.

The Panchets of the Káranpúra field occupy a considerable tract in the middle of the field, they and the overlying Mahádevas composing the surface throughout 90 square miles. The Panchets consist chiefly of coarser sandstones than those of the Bokáro field, and they are less micaceous. Red clays are common in the middle and upper portion of the group, but they are not distributed in thick beds as in the Ránigaṇj field; they are thinly laminated, and alternate with green micaceous clay.

The Mahádevas form the hills of Maudih and Sáthpahári in the middle of the field, besides a few scattered outliers, another rise about 3 miles long near Ganeshpúr on the west of the area, and Gerwa hill to the south-west. Of these Maudih hill is by far the most extensive; it is a plateau about 11 miles in length from east to west, and 5 from north to south. The rocks are the usual coarse sandstones, grits and conglomerates. In the south-eastern spur of this hill there is a remarkable example of the unconformity between the Mahádevas and the lower Gondwána series (Panchets and Damúdas), the conglomerates of the former resting upon Barákars faulted against Ránigaṇj beds.[1]

One remarkable point about the Káranpúra field is the paucity of the basaltic dykes so abundant in the eastern Damúda coal-fields. This

[1] In the map published in the Memoirs there is a mistake, the Mahádevas or Upper Panchets at this spot being coloured as Panchets proper.—See Mem. G. S. I., VII, p. (320).

probably indicates that the Káranpúra area is near the limit of the old outbursts of Rájmahál times. Further to the westward no dykes are found in the coal-fields until the area of the Deccan trap is entered. Faults too are less prevalent than in the other Damúda fields, and there appears thus some reason for connecting the origin of the principal dislocations in the Ániganj neighbourhood with the disturbances which preceded the outburst of the Rájmahál traps.

The country west and south-west of the Káranpúra fields has hitherto only been partly and imperfectly surveyed, and it is probable that closer examination may shew the occurrence of several small outliers of Gondwána beds hitherto unknown. The existence, on an isolated hill called Madaghir, 3 miles west of the Káranpúra field, of some sandstones belonging to the Gondwána series, has already been noticed.

B.—Coal-fields of Northern Hazaribagh, Southern Behar, and Palamaun (Palamow).—In this section will be comprised the fields of Chopé, Itkúri, Daltonganj, a small tract of Tálchir rocks near Shergotty, and a few other basins which have not yet been surveyed. The Daltonganj field, and all the other areas named, except Chopé and Itkuri, might equally well be referred to the next sub-division, as they are in the Son (Soane) drainage, but it seems best on the whole to place them here. There is, in fact, no line to be drawn between the Bengal and Behar fields and those of Chutia Nágpúr and South Rewah, and there appears to be a very great probability that all were once part of a continuous area.

7. Chope.—This is probably the smallest tract of Gondwána rocks containing coal yet detected in India. The peculiar interest attaching to this small area, from its position on the top of the Házaribágh plateau, has been already noticed.

The Chopé field,[1] which is traversed by a stream called the Mohani, is about 8 miles west by a little north of Hazáribágh, and at nearly the same elevation as the station, or about 2,000 feet above the sea. Small as the field is, it offers a repetition of some of the characteristic features of the Damúda coal basins. It is subtriangular in form, about a mile and a half in extreme length, from west by north to east by south, and rather less than a mile broad in a direction at right angles to the length, and it consists of Tálchir and Barákar rocks dipping to the southward with an anticlinal roll in the middle, and cut off along the southern border by a fault running from west by north to east by south.

The Tálchirs skirt the field and reappear in a small inlier, produced by the anticlinal roll above mentioned, and surrounded by Barákars, in

[1] A description by Mr. Ball is given in Mem. G. S. I., VIII, pp. (347)-(352).

the middle of the area. The beds of the Tálchir group consist of fine greenish sandstones with the boulder bed. The Barákars occupy the remaining tract. Only a small thickness of them is exposed in the only section available, that seen in the Mohani stream, but they comprise one bed of very shaly and inferior coal about four feet thick. The rocks of this small field are very poorly exposed.

8. **Itkuri.**—The Itkúri coal-field[1] lies about 25 miles north-west of Hazáribágh, and nearly as far north of the Káranpúra field. It is 15 miles long from east to west, but very narrow, being nowhere more than 2 miles broad, and the whole area consists of Tálchir beds, with the exception of one small patch, about half a square mile in extent, occupied by Barákars. The boundaries are mostly natural, a small fault cutting off the only outcrop of Barákar beds to the north-east, and bringing up metamorphic rocks against it. Neither Tálchir beds nor Barákars present any peculiarities; the latter contain some beds of inferior coal.

Two areas of Tálchir rocks are mentioned in the description of the Daltonganj field[2] as being found in the Hazáribágh district, besides those already mentioned. Both occur on the road from Balumáth to Chutro in Lohárdagga.

9. **Daltonganj.**—This coal-field has been known for many years under the name of Palámaun (Palamow), and the coal was worked formerly and sent down the Son river to the Ganges. The name of Palámaun, which is that of a sub-district or parganah of the district (zillah) of Lohárdagga in Chutia Nágpúr, being inapplicable, because other tracts of sedimentary rock occur within its limits, Mr. Hughes substituted that of Daltonganj, the civil station lying just beyond the southern border of the field.[3]

The Daltonganj coal-field, which is traversed by the Koil river, a tributary of the Son, lies about 50 miles nearly due west of Hazáribágh, and is a long irregularly-shaped tract, with very tortuous boundaries. It extends about 50 miles in length from east to west, and varies in breadth from 1 to 8 miles, its total area being 200 square miles. It is basin-shaped, the boundaries being apparently natural. Several inliers of gneiss occur within the limits of the field, but they are not extensive. Some small outliers of Tálchirs are scattered around the field.

The only formations represented are the Tálchirs and the Barákar sub-division of the Damúdas. The former are about 500 feet thick, and comprise the usual rocks, sandstones being more prevalent than shales, whilst the boulder bed is well developed. The Tálchir beds occupy more than four-fifths of the area. The Barákars are restricted to a tract nearly

[1] For description by Mr. Hughes, see Mem. G. S. I., VIII, pp. (321)—(324).

[2] l. c., p. (346).

[3] For a description of this field by Mr. Hughes, see Mem. G. S. I., VIII, pp. (325)—(346).

10 miles in extreme length from north-west to south-east, and 4½ broad, with an area of 30 square miles. The lithological character of the group is different to what it is in the Damúda coal-fields, the sandstones, which form the bulk of the formation, being friable, slightly calcareous, yellow in colour more frequently than white, composed of alternating fine and coarse layers, and very false bedded, the general appearance being intermediate between typical Barákars and typical Ániganj sandstone. It must be borne in mind that this field is beyond the area within which the Rániganj group has been found to exist.

Seams of coal are few in number, and only one, which contains about 5 or 6 feet of fair coal, is of sufficiently good quality and thick enough to be of value. It varies in thickness.

Only one intrusion of basaltic rock has been found in this field.

10. Unsurveyed basins in Palamaun and Lohardagga.—In the description of the Káranpúra field, mention has already been made of the probable occurrence of several small basins of Gondwána rocks in the country to the west and south-west of the Upper Damúda valley. Two of these outcrops have been briefly mentioned[1] by Mr. Hughes. They are the following:—

Sathbarwa.—This is a halting place 15 miles south-east of Daltonganj on the road to Ranchi. Only Tálchirs have been observed.

Latiahar.—This is another halting place on the same road 26 miles south-east of Daltonganj. Tálchirs, Damúdas (Barákars), and Mahádevas occur, the latter being largely developed. The Barákar beds are unusually ferruginous, and are consequently not easily distinguished from the overlying Mahádevas. Very little coal has been detected.

Several other small basins are known to occur in the Palámaun country, and the extent of ground over which they may be found cannot as yet be accurately defined. Far to the south on the top of the Chutia Nágpúr table-land, there is a report of coal occurring near Khurea, 24 miles north-west of Jashpúr. This report, however, depends solely on native information, and there is much reason to doubt its accuracy.

The last outcrop to be mentioned lies as far to the north of Palámaun, as the Jashpúr basin, if it exist, would be south.

11. Morhar River, south-west of Sherghotty.—At the small village of Gangti, 20 miles south-west by west of Sherghotty, and 4 miles west by south of Emámganj, there is a small exposure of Tálchir beds in the bed of the Morhar river. The only interest attaching to this outcrop is due to its occurrence on the edge of the Gangetic alluvium and the consequent indication of a possibility that Gondwána rocks may exist, beneath the alluvial formations, in this part of the Gangetic plain.

[1] Mem. G. S. I., VIII, p. (346).

CHAPTER IX.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF COAL-FIELDS, ETC.

IV. SON, MÁHÁNADI AND BRÁHMANI REGION — 1, South Rewah and Sohágpúr — 2, Jhilmilli — 3, Bisrampúr — 4, Lakhanpúr — 4*a*, Outcrops in Chutia Nágpúr — 5, Korba — 6, Raigarh and Hingir — 7, Tálchir. Outliers of Tálchir beds in Máhánadi valley. V. SÁTPÚRA REGION — 1, Sátpúra basin — 2, Upper Tapti area — 3, Small areas on the lower Narbada, west of Hoshangabád.

IV. Son (Soane), Mahanadi, and Brahmani region.—The area occupied by the Gondwána formations in the centre of India differs greatly from that in Bengal. In the central region the sedimentary beds, instead of being scattered over the metamorphic country in a number of small detached basins, occupy an enormous tract extending from Jabalpur on the west to Sirgúja on the east, and from a little south of the Son to the neighbourhood of the Máhánadi near Sambalpúr. To the westward the sandstones disappear beneath the Deccan traps, and may be continuous under the covering with the Sátpúra basin. To the south-east a long narrow strip of Tálchir rocks all but connects the tract north of Sambalpúr with the Tálchir basin in Orissa. A glance at the map will show that, but for the overlying volcanic formations, there would be an almost unbroken band of Gondwána beds across the Peninsula, from near Hoshangabád in the Narbada valley to within 40 miles of Cuttack in Orissa, or throughout eight degrees of longitude.

No portion of this area has been geologically surveyed as carefully as the coal-fields of Bengal. The Sátpúra field, some detached portions of the great central mass, comprising its north-eastern corner near Singrauli, three small tracts in Sirgúja, and another forming the south-eastern corner of the main area near Sambalpúr, together with the Tálchir field in Orissa, have been more closely mapped than any others; whilst the enormous area in South Rewah, Sohágpúr, Bilaspúr (Chhatísgarh), Northern Sirgúja, and Udepúr (Chutia Nágpúr), has been only cursorily examined, and in some cases merely traversed.

In the western coal-fields of the Damúda valley, there is a diminution in thickness of the whole Gondwána system, mainly due to the

gradual thinning out of all the groups between the Barákars and the coarse, ferruginous sandstones and conglomerates which were formerly classed as Upper Panchets, and have been in this work referred to the Mahádeva series, and considered as of upper Gondwána age. This gradual disappearance of the intermediate groups is carried so far that in places the Mahádeva conglomerates rest directly on Barákar rocks. The same combination, a thick mass of sandstones, more or less conglomeratic, resting immediately on Barákars, prevails, so far as is yet known, in the upper Son valley (Soh́agpúr and South Rewah) and throughout the Bilaspúr, Sambalpúr, and Tálchir coal-fields, but it is now clearly ascertained, in the neighbourhood of Sambalpúr, that the lower portion of the upper beds is of Damúda age. Precisely the same sequence occurs in the Godávari valley, where also the most conspicuous change in lithological characters, accompanied by unconformity, occurs between the Barákar beds and the next formation in ascending order, and where the group immediately succeeding the Barákars contains Damúda fossils. There is, therefore, a marked agreement between the Gondwána groups in the Godávari and those in the Máhánadi and Bráhmani valleys. How far the same classification should be applied in South Rewah remains to be seen, but it is certain that Damúda fossils occur in places at a higher horizon than that of the Barákar group.

In the Sátpúra area the rocks are very different. A full series of lower Gondwána beds is succeeded by an equally complete sequence of upper Gondwána strata. The middle group of the Damúda series greatly resembles, in lithological character, some portions of the upper Gondwánas, but, as a general rule, there is a marked contrast between the upper and lower sub-divisions of the system. It is consequently desirable to treat the Sátpúra region as a distinct section.

It is not practicable to sub-divide the remaining area, although it is extremely probable that when the formations of South Rewah, Sirgúja and Bilaspúr are better known, differences will be found which will justify the conclusion that the upper Gondwána beds in the north and the south were accumulated under different circumstances; still the fact that the Gondwána rocks are continuous from near Jabalpur to the neighbourhood of Sambalpúr, renders it impossible at present to draw a satisfactory line. In the present section, therefore, a brief account will be given of the principal tracts on the Son, Máhánadi, and Bráhmani valleys. It should be repeated that these coal-fields, with the exception of that near Tálchir, are not separated from each other by metamorphic rocks; in some cases they are connected by broad plains of Tálchir beds, and elsewhere they are merely inliers, exposed amidst hills of higher

sandstones, still belonging to the Gondwána system. The following areas will be noticed separately :—

1. South Rewah and Sohágpúr.
2. Jhilmilli.
3. Bisrampúr.
4. Lakhanpúr.
4*a*. Outliers in Chutia Nágpúr.
5. Korba (including Rámpúr and Udipúr).
6. Raigarh and Hengir.
7. Tálchir.

1. South Rewah and Sohagpur.—Of this enormous tract only a most imperfect account can be given.[1] Leaving out of consideration the extension to the westward along the edge of the trap country to Jabalpur, the area of Gondwána rocks stretches nearly 200 miles from east to west, from the Kánher Singrauli to the Son-Máhánadi[2], and for a considerable distance the tract is 60 miles broad.

So far as can be judged from the very imperfect examination hitherto made of this field, it agrees better in its petrography, and in the arrangement of the rocks composing it, with the area to the westward in the Sátpúra region, than with the Gondwána series in the Damúda valley. There is a general tendency to a northerly dip throughout the western part of the area, and again in the tract of Damúda rocks to the north-east in Singrauli. The northern boundary runs from east-north-east to west-south-west, and is for a considerable distance nearly parallel with the general course of the river Son, at a distance of from 5 to 20 miles south of the river. This boundary is very straight and of an abrupt character, and in places it is clearly a fault; fragments, both of Damúda sandstones and of the crystalline rocks which occur outside the Gondwána area to the north, being found crushed together into a breccia along the line of junction. The higher rocks, of later age than the Damúdas, occupy the area to the northward, in the western part of the Gondwána tract, near the upper Son (Sohágpúr), but they appear thence to extend to the eastward south of the Damúda area in Singrauli. In the western part of the area these higher beds overlap the lower Gondwána series and rest on transition rocks. The eastern boundary

[1] No general description has ever been published. The extreme western portion was comprised in Mr. J. G. Medlicott's account of the geology of the central portion of the Narbada district; Mem. G. S. I., Vol. II, pp. 97-270. Such details as are given of the remaining area are from manuscript reports by Messrs. J. G. and H. B. Medlicott and Mr. Mallet.

[2] Not to be confounded with the Máhánadi of Chhattisgarh and Orissa. There are several rivers of this name (which only means great river) in India.

is irregular, the Mahádevas extending far to the eastward in Sirgúja. To the south-east the boundary of the area now under discussion is formed by the Tálchir rocks, which connect it in that direction with the other Damúda tracts in Sirgúja and Chhattisgarh; to the south the Tálchir beds rest upon the gneiss, whilst to the south-west the whole Gondwána series is gradually overlapped by the Deccan trap scarp extending to the north-west from Amarkantak, and by the Lametas underlying the traps. These overlying rocks, where they first impinge on the area from the southward, conceal only the lower members of the Gondwána system; the higher members extend farther to the westward, and the highest of all, belonging to the Jabalpur group, form a narrow and interrupted band, extending at intervals round the northern margin of the Mandla trap plateau to Jabalpur in the Narbada valley. From the manner in which the Gondwána rocks disappear beneath the traps of this plateau, there is considerable probability that the former continue to some extent beneath the latter, and the South Rewah and Sátpúra areas may be parts of one continuous tract of Gondwána rocks.

Despite the imperfect knowledge as yet available of the geological details, it is clear that the principal sub-divisions of the Gondwána system, the Jabalpur, Mahádeva, Damúda, and Tálchir formations, are all represented in the South Rewah area. The Tálchirs occupy a large crescent-shaped tract of country in the north-east corner, on the Rehr or Rehand river, in south-eastern Rewah and Singrauli, the length along the curve of the crescent being about 50 miles, with an average breadth of 5 to 6. There are some smaller Tálchir outcrops in the same neighbourhood along the northern boundary of the Gondwána tract, but the largest is only 3 or 4 miles across. The great expanse of Tálchirs is south of the field, where these beds cover a tract, several hundreds of square miles in extent, around Korea, west of Sirguja, and extend thence to the westward until they disappear beneath the Amarkantak traps. As already mentioned, this expanse of Tálchirs has been accepted as the southern boundary of the South Rewah Gondwána basin.

The Damúdas are represented by the Barákars throughout the field, and this group, being of economic importance on account of its containing coal, has received more attention than the other beds. There appears, however, good reason for believing that some of the higher Damúda sub-divisions are represented to the westward in Sohágpúr, because true Damúda plants were found by Mr. J. G. Medlicott in beds which he had at first classed as "Upper Damúda," *i. e.*, Jabalpur, and, as will be seen presently, there are some indications of the occurrence of an upper sub-division in South-Eastern Rewah.

In the Singrauli area and the neighbourhood of the Rehand valley, the Damúdas consist principally of coarse felspathic sandstones, shales being less abundant. The rocks dip at low angles, or are nearly horizontal. Coal has been found in several places, as at Kota, Nowanagar, Parari, &c., and although the seams, as a rule, are thin, that at Nowanagar is an exception, being upwards of 20 feet in thickness, and a portion being of good quality. In one case a conglomerate containing rolled pebbles derived from the Tálchirs was found by Mr. Mallet in the Barákar beds.

Further west, on the Gopat river, there is a great thickness of coarse felspathic sandstones with occasional flaggy beds, shales, and seams of coal, all of which, however, so far as they are known, are inferior. Beneath the massive sandstone, however, there are flags and shales with some coal seams, and below these again more sandstone, associated with which, at Keryli, there is a seam of coal about 5 or 6 feet thick and said to be of excellent quality. It is possible that in this case the upper sandstone represents the Ránigan j group of the Damúda valley.

To the west of the Gopat valley the Barákars appear to be covered by higher members of the Gondwána system. The former crop out again to the south and south-west, and occupy a very large area in the valley of the upper Son in Sohágpúr, where the river runs from south-east to north-west parallel to the scarp of the Amarkantak plateau. From the Son valley the Damúda tract extends to the east as far as Jhilmilli, south of the great upper Gondwána belt.

An excellent section of beds of Damúda (and probably Barákar) age is exposed in the Johila river, a tributary of the Son in Sohágpúr; a thickness of 3,000 feet altogether being exposed, including the Tálchirs. The Damúda rocks consist of sandstones above, shales and flags below, the seams of coal associated with them being of poor quality and thin. The same appears to be the case in the area to the eastward so far as it has been examined.

Above the Damúdas the typical Mahádeva sandstone, pebbly, false-bedded, and with thin bands of hard ferruginous shale, brick-red to dark-brown in colour, has been traced across the whole region, and it is mainly on the strength of this evidence that the Mahádevas of the typical Sátpúra area are correlated with their probable representatives in the Damúda valley. The Mahádeva group is probably, in South Rewah as elsewhere, unconformable to the underlying formations.

The higher groups are only known to the westward in Sohágpúr and south-west Rewah. They consist of a great thickness of coarse felspathic sandstone, forming, amongst other hills, that on which stands the hill fort of Bandúgarh, and resting upon lavender-grey and white shales.

Both the sandstones and shales are referred to the Jabalpur group, the characteristic fossils being found abundantly in the shales. With these shales there is associated locally a band of coal of peculiar character, consisting of fine layers of jet. A very common character of the Jabalpur beds in this area is local induration, the sandstones having the texture of a quartzite, whilst the shales become porcelanic.

Basalt dykes occur throughout the South Rewah and Sohágpúr area, and some of the hills of sandstone in Sirgúja are capped by overflowing trap. In places some dykes are horizontal, and certain basalts, apparently interstratified with the Barákars of South-Eastern Rewah, may be examples of horizontal intrusion, but they are thought by Mr. Mallet to have a close resemblance to contemporaneous lava flows. All the basalt, whether intrusive or overlying, with the possible exception of the case just mentioned, appears to belong to the date of the Deccan traps.

2. Jhilmilli.—At the eastern extremity of the great area of Damúda beds which extends to the eastward from Sohágpúr,[1] there is a small tract of Barákar rocks, known as the Jhilmilli field from a town of that name at its eastern extremity. This little field lies due west of the northern portion of the Bisrampúr field, from which it is only separated by a belt of metamorphic rocks not much more than 3 miles broad. It is possibly an integral portion of the South Rewah and Sohágpúr field, but it is separated from that field by a fault, and it is nearly isolated.

This little tract is about 25 miles in extreme length, but only covers about 35 square miles. It is south of the fault just mentioned which runs from east-north-east to west-south-west, or parallel to the fault bounding the northern edge of the South Rewah field. The rocks of the Jhilmilli field dip northward, and are cut off at the fault in the usual manner. To the north of this fault throughout the eastern half of the field, metamorphics occur, with large patches of Tálchirs, filling all the hollows; but further to the westward, towards Sanhat, Damúda beds may be found, the area not having been examined. To the southward is a great expanse of Tálchirs with gneiss inliers of large size, the Damúda beds resting usually on Tálchirs, but occasionally on metamorphic rocks. The only beds of later age than Barákars known to occur in the field are those of the hills of Káltanghát, Chama, and Tumarbári, which are probably either Kámthi or Mahádeva.

The Tálchirs around this field are chiefly remarkable for two circumstances. One of these is the occurrence in abundance, amongst the

[1] These notes are from a manuscript account by Mr. Ball.

boulders, of masses composed of the characteristic compact Vindhyan sandstone, approaching quartzite in character. The nearest source of this rock is in the Kymore scarp beyond the Son river, 70 to 80 miles distant to the northward. Similar rocks also occur to the southward in Chhattisgarh and Sambalpúr, but the distance is even greater. It is not probable that the boundary of the rock in this instance was very much nearer in the Tálchir days, because so large a portion of the intervening area is occupied by Gondwána formations, and these nowhere rest upon Vindhyan rocks within the limits mentioned.

The other remarkable circumstance is the occurrence amongst the Tálchir rocks of a very thin seam of carbonaceous shale and coal. This bed is only about 6 miles in thickness, and the coal is of inferior quality, but its occurrence in the Tálchirs is remarkable and unusual.

The Barákars present no peculiarity. Several coal seams occur, and some are of excellent quality, but none appear to be of great thickness.

The upper rocks of the Káltangһát and other hills are but imperfectly known, and are only provisionally referred to the Mahádevas. Some trap dykes are met with in this field.

3. **Bisrampur.**—The Bisrampúr field is a tract chiefly composed of Damúda rocks, in Central Sirgúja, and derives its name from the chief town of the Sirgúja territory.[1] This field is connected by the great expanse of Tálchirs on its western side with the Jhilmilli, Sohágpúr, and South Rewah fields, and to the southward with the Korba, Raigarh, and other tracts of the Máhánadi valley. The Bisrampúr field lies south of the great belt of Mahádeva rocks extending to the eastward into Sirgúja, and is separated from the Mahádevas by a rather broad metamorphic region.

The field is nearly rectangular in shape. It is about 24 miles in extreme breadth from east to west, 22 miles from north to south, and it comprises about 400 square miles. The northern boundary runs nearly east and west, and is marked as a fault throughout; the southern boundary is also faulted, and has a direction from west by north to east by south; the east and west boundaries are for the most part natural.

The rocks exposed are the following:—

	Approximate thickness in feet.
Mahádeva ?	1,000
Damúda (Barákar)	500
Tálchir	200

The thickness assigned to the beds, with the exception of the Mahádevas, are mere approximations. The strata are, on the whole, nearly horizontal; they are greatly concealed by alluvium, and the only sections seen are in the beds of streams.

[1] Described in detail by Mr. V. Ball—Rec. G. S. I., VI, pp. 25-41.

The Tálchirs present no peculiarities. To the west and south they are portions of the great area outside the field; they are represented by two patches of small extent outside the northern border, and they skirt a considerable portion of the eastern margin of the field, extending in places up the valleys between the ridges of metamorphic and transition rocks. The original surface on which they were deposited around the Bisrampúr field appears even more irregular than usual, and in one instance a ridge of quartzite penetrates the field for 6 miles with Barákars abutting against it on both sides.

The boulder bed is well developed at the base of the Tálchirs, and occasionally, as usual, contains boulders brought from a distance. In one case, in the northern part of the field, the source of some granitic gneiss blocks was traced to a locality 3 miles away to the north.

The Barákars, although occupying so large an area, are but ill seen, the rock most commonly exposed at the surface being whitish grit or sandstone, occasionally containing pebbles. Coal seams are found in several places, but they are not very promising, many of them containing but inferior fuel, whilst none are more than 5 or 6 feet thick. Good coal has, however, been found in places.

Mahádevas only occur in the southern part of the field, where they form a range about 6 miles long, known as the Pilká hills. They consist of the usual grits and pebble conglomerates with hard quartzose sandstones, but they are less ferruginous than elsewhere.

Although these rocks are assigned to the Mahádeva group of the upper Gondwánas on account of their neighbourhood to beds belonging to that formation in the South Rewah area, it must be borne in mind that no fossils have been found in them, and that lithologically they are undistinguishable from the Kámthi beds of the Raigarh and Hingir field, in which fossils have been found.

The most interesting point about the Mahádevas (or Kámthis) in this field is the conclusive evidence afforded by them of unconformity to all the lower formations. Not only do they rest partly on Damúda and partly on Tálchir beds, and, overlapping both, rest upon the metamorphics, but they overlie the lower Gondwána groups in places where the latter are distinctly faulted against each other, the fault not passing into the Mahádevas above. Faults between the Tálchirs and metamorphics are also unconformably covered by the Mahádeva sandstones.

4. **Lakhanpur.**—Another small area of Barákars, the western portion of which has not been fully examined,[1] lies due south of the

[1] This field, like the preceding, has been mapped by Mr. Ball, and the following short account is from his manuscript notes.

Bisrampúr field, from which it is only separated by a belt, two to three miles broad, of Tálchirs with inliers of gneissic rocks. On this belt of Tálchirs, further east, rests the Mahádeva mass forming Pilká hill, which is only a mile from the north-eastern corner of the field. The name of the present field is derived from a town lying outside the south-eastern edge of the Gondwána area.

The Lakhanpúr field is about 9 miles long from north to south; its breadth has not been determined, its western extent being unknown. The northern and southern boundaries are faults; the eastern boundary for the most part appears to be natural. No beds above the Barákars are found within the area, which is much covered by alluvium, the only rocks exposed, as a rule, being in the river sections, which are numerous.

Several seams of coal are exposed, the best being one seen in the Chandnai stream at Katkona. This seam is 5½ feet thick where best seen, one half consisting of excellent coal, the other half being of rather poorer quality. Several trap-dykes are found in this field.

4a. Outliers in Chutia Nagpur.—These are, as a rule, of small importance and but little known. None has as yet been mapped, and it is quite uncertain how many there may be. It is certain that small patches of Tálchir beds are scattered throughout many of the valleys of Eastern Sirgúja, Udepúr,[1] &c., but none have as yet been traced on the main plateau of Chutia Nágpúr.

Some of the flat-topped hills in eastern Sirgúja are capped by plateaus of sandstone, belonging apparently to the upper Gondwána series. In some instances, as on Main Pat, a high plateau north of Udepúr, this sandstone is covered by basaltic trap, belonging evidently to the Deccan trap series, which is again capped by laterite. The sandstone on Main Pat is about 300 feet thick; it rests north of the plateau on Tálchir beds, elsewhere on metamorphics in general, though Tálchirs appear beneath it here and there. The Tálchirs to the north of the plateau extend in the form of a belt from 2 to 4 miles broad, for 16 miles north to Bisrampúr, where they dip under Barákars. One outlier of the Mahádeva sandstone rests on these Tálchirs, another on a hill of metamorphic rocks close by.

5. Korba, (Rampur, Korba, and Udepur.)—Only the northern and eastern portions of this tract have been surveyed, and that but partially; the remainder of the area is only known by traverses.[2] The

[1] Not to be confounded with Udepúr in Rájputána, nor with another State of the same name in the lower Narbada valley.

[2] The coal at Korba is described in Rec. G. S. I., III, p. 54. The Udepúr portion of the country is known from Mr. Ball's manuscript notes.

Rámpúr, Korba, and Udepúr field evidently forms an integral portion of that next to be described; and had a complete survey of the country been carried out, the two would have been described together. The small town of Korba, on the Hasdo river, being the best known locality for coal, gives its name to the field.

The tract of Gondwána rocks running southwards from Sirgúja expands considerably in breadth south of the lofty plateau of Main Pat, and west of Udepúr, and extends between 40 and 50 miles from east to west, or from east of the Mánd to west of the Hasdo. To the northward, west of Main Pat, this area is nearly cut off by metamorphic rocks west of Lakhanpúr, the only connection between the Korba area to the south and the Lakhanpúr field to the north being by means of a belt of Tálchir rocks 3 or 4 miles long. To the southward the Gondwána area extends down the Mánd to Gúrda. Altogether, the present field is about 80 miles in length from north to south.

The greater portion of this large tract of country appears to be composed of Barákar rocks. Tálchirs of course are scattered in the usual patches, sometimes filling up hollows in the previously-formed metamorphic surface, on the outskirts of the tract, whilst higher sandstones—whether belonging to the upper Gondwána series, (Mahádevas,) or representing the Kámthi beds of the Raigarh-Hingir field is not clear—extend in detached masses along the eastern side of the field, having been doubtless connected originally with the beds of Main Pat. Towards the south these upper beds form the great range of hills which separates the area of Damúda rocks on the Mánd from that on its tributary, the Kurkut.

Trap of the Deccan series caps some of these hills of the higher sandstones in the northern portion of the field. This is the case with the hill of Rámgarh in South-Estern Sirgúja; and there appear to be other outliers towards Main Pat.

Coal occurs in many places on the Mánd and elsewhere near Udepúr, several of the seams being of fair thickness and average quality, whilst at Korba an immense seam of coal and carbonaceous shale is exposed in the bed of the Hasdo. This seam is at least 90 feet in thickness, the greater portion, however, being very shaly, and all containing a large proportion of ash. Some of the coal, nevertheless, appears to be of sufficiently good quality for use.

6. Raigarh and Hingir.—This, the south-eastern extremity of the great Son-Mahánadi area of Gondwána rocks, was formerly known as the Gángpúr field, but as no portion of it is in the Gángpúr

territory, the present name was substituted by Mr. Ball.[1] The Raigarh and Hingir field is named from the two estates in which it is principally comprised; it consists of a belt of sedimentary rocks, rather more than 20 miles in breadth near Raigarh, extending for nearly 90 miles to the north-west from the neighbourhood of Sambalpúr, gradually diminishing in breadth to the south-east, and terminating in that direction in a long narrow tongue of Tálchir beds which extends for between 30 or 40 miles, and comes to an end close to the edge of the Tálchir coal-field. The north-western extension of this field forms that of Korba and Udepúr, briefly described in the preceding paragraphs. The south-western limit of the field is straight and faulted for a long distance.

The rocks found in the Raigarh-Hingir area consist of—

	Approximate thickness in feet.
Kámthi or Hingir group	1,000
Barákar	?
Tálchir	250

The Tálchirs present their characteristic features. They occupy the south-eastern corner of the tract, and, as already mentioned, the strip which serves nearly to connect it with the Tálchir field, and they appear in several places underlying the Barákars on the margin of the Gondwána area.

The Barákars occupy several isolated tracts. They occur on the Mánd river to the north-west, and there form part of the area stretching northwards to Udepúr and west towards Korba. East of the Mánd river this Barákar tract is covered by higher beds, which extend for about 10 miles before Barákars again appear, and occupy a considerable area, about 25 miles in length from north-west to south-east, in the north-eastern corner of Raigarh. Of this area about 200 square miles have been examined. They form a large inlier, entirely surrounded by beds of higher formations. Barákars also occupy a considerable tract of country in the south-east of the field, and a narrow strip of them extends up each border. In many places they overlap the Tálchirs, and rest on the metamorphic rocks throughout considerable distances, as, for instance, along the north-eastern boundary of the field for about 20 miles north-west of Rájpúr.

The Barákars consist of felspathic sandstones and grits, shales and coal. A great thickness of shaly beds, amounting altogether to about 500 feet, with coal seams and occasional intercalations of sandstone, is

[1] For fuller accounts of this field by Mr. Ball, see Rec. G. S. I., IV, pp. 101-107; VIII, pp. 102-121; and X, pp. 170-173.

exposed in the Baisundar river, north of Hingir. Elsewhere, the rocks exposed appear to consist chiefly of sandstones and conglomerates. In the neighbourhood of Rámpúr, north of Sambalpúr, the Barákars contain much brown hæmatite in nests and irregular bands. Of the coal seams known, the majority are thin and poor, but a few are more promising.

The Barákars have a general low dip towards the south-western border of the field; the amount is small, not exceeding 5° to 10°, and there is a considerable amount of rolling.

The Kámthi beds consist of coarse ferruginous sandstones and conglomerates, and beds of red shale, having altogether a Mahádeva character; no carbonaceous bands have been observed amongst these rocks. They form great masses of flat-topped hills, and are very nearly horizontal, and consequently unconformable to the disturbed and inclined Barákars beneath them. They resemble the Kámthis of the Godávari valley in lithological character, and they contain *Glossopteris browniana, G. indica, Vertebraria, Alethopteris lindleyana,* and *Schizoneura gondwanensis,*—all Damúda species which have never been found in the upper Gondwána series.

These beds occupy the greater portion of the field, the Barákars appearing from beneath them. The Kámthis overlap the Barákars north-west of Hingir, and rest upon the metamorphics. The streams cut deep gorges through the upper sandstones, and the underlying rocks are frequently exposed in the bottom of the valleys. Along the south-western boundary, the Kámthi sandstones are, for a considerable distance, faulted against Vindhyan rocks.

Some of the coarse sandstones may represent a higher horizon. It is, however, most difficult to trace separate divisions in a mass of sandstones all similar in character, and in which fossils are very rare.

Only one trap-dyke has been found in this area; the rocks traversed by the dyke are Barákars. A considerable quantity of laterite covers portions of the field.

7. Talchir coal-field.—This basin is named from the small town of Tálchir on the Bráhmani river, the residence of a petty rajah who owns a considerable portion of the country in the neighbourhood. The Tálchir coal-field was one of the tracts of Gondwána rocks first examined by the present Survey; it was actually the first of which any detailed account was published, and it is the area in which the distinctions between some of the different members of the series were first clearly ascertained—a circumstance commemorated by the name which has since been applied to the lowest of them.

The Tálchir coal-field[1] commences, as already noticed, only 3 or 4 miles south-east of the point where the long spur of Tálchir rocks extending eastward from the Raigarh-Hingir field terminates. The present tract is about 70 miles in length from west by a little north to east by a few degrees south, and it is nearly 20 miles broad where widest. Its area is rather less than 700 square miles. Nearly the whole field is comprised in the drainage area of the Bráhmani river, only the extreme western and south-western portions being within the Máhánadi watershed. The northern boundary is abrupt and faulted throughout; the southern boundary over part of its extent only. The evidence of faulting in the case of the northern boundary is more complete in this field than usual, the fault being divided and bringing portions of the lower beds to the surface between the divided branches, whilst the dislocation itself is marked by a quartz vein and a mass of breccia containing fragments of the sedimentary beds, precisely as in the similar case mentioned already as occurring in South Rewah. In the eastern portion of the field the general dip is north, increasing in intensity near the faulted northern boundary, but great rolls of the strata take place throughout this portion of the field, whilst to the westward the whole area is occupied by nearly horizontal beds belonging to the upper sub-divisions.

The groups represented in this field and their approximate thickness are the following:—

Mahádeva ? } Kámthi }	1,500 to 2,000 feet.
Barákar	about 1,800 „
Tálchir	500 feet.

The Tálchirs occupy the south-eastern corner of the field; they reappear between the branches of the fault forming the northern boundary, and they are represented in the extreme west of the field, where they form the usual tongue-shaped extensions occupying old hollows in the metamorphic rocks. This field is the typical locality for the group; and all the usual constituent beds—boulder beds, shales, and sandstone—are well developed and characteristic. The boulder bed occurs at the base, the matrix being sometimes shale, sometimes sandstone, then follows fine greenish-grey tesselated sandstone, and, at the top of the group, there is a considerable thickness of nodular shale, in which pebbles and boulders are occasionally found. Some annelid (or molluscan) tracks and a few fragments of plants have been found in these beds.

[1] See Mem. G. S. I., I, pp. 33-88. The field has recently been re-examined by Mr. Ball, who has confirmed all the main features of the original mapping, and has added some important details, especially as to the relations of the higher beds in the field. See Rec. G. S. I., X, pp. 170-173.

The Damúda group is represented by both Barákars and Kámthis; the latter were originally described as Mahádevas, but further research has shewn that there can be scarcely any doubt of some of the beds in the western portion of the Tálchir field being identical with the upper group of the Raigarh and Hingir field. The Barákars occupy a very large tract in the eastern portion of the field, in which they stretch from the northern border nearly to the southern. They are also represented at one place in the extreme west of the field near Tipapáni in Rairakol, but, as a rule, to the westward, they are overlapped by higher beds. They are distinctly unconformable to the Tálchirs, and consist of white felspathic sandstone, coarse grey and brown grits, blue and carbonaceous shales, and some beds of inferior coal. At the best known coal locality, Gopálprasád, about 12 miles west of Tálchir, the combined seam of coal and carbonaceous shale is of great thickness, probably not less than 100 feet, in this resembling the seam already mentioned as occurring at Korba on the Hasdo, and the coal seams of Chánda in the Godávari area.

The upper beds are unconformable to the Barákars, the unconformity being not only shewn by overlap, but actually seen in a section at Patrapáda on the Medúlea stream and at another near Tipapáni.

The rocks resting upon the Barákars near Patrapáda consist of yellow and white sandstones with purple clays having some resemblance to the upper Kámthis near Chánda, and also to some of the Panchet beds in the Damúda valley. The beds near Patrapáda attain a thickness of at least 600 feet, and appear to be more disturbed than the conglomerates and grits which rest upon them. Similar sandstones and clays are found in other parts of the field, and, although no fossils have been found in them, they may be referred, with much probability, to the Kámthi group, like the rocks of the Raigarh–Hingir field.

The beds forming the higher portions of the hills, in the western part of the Tálchir field, consist of grits and conglomerates containing pebbles of gneiss, quartzite and sandstone; some of the sandstone fragments closely resemble Tálchirs, but may be derived from certain Vindhyan beds which are very similar to Tálchirs in mineral characters. These conglomeratic upper beds are all more or less ferruginous, and contain bands of jaspery ironstone like those in the Mahádevas of the Sátpúra hills and the Kámthis of Nágpúr. The apparent difference in the degree of disturbance, to which the beds supposed to represent the Kámthi group on the one hand, and the overlying conglomerates on the other, have been subjected, has already been mentioned; it appears probable that the last named represent some upper Gondwána formation, and

they may be referred to the Mahádeva series. They exhibit some resemblance to the Rájmahál beds of Atgarh near Cuttack. In the Ouli river south of Patrapáda the upper conglomerates are about 800 feet thick. The examination of the beds above the Barákars in the Tálchir field is very difficult, as the upper members of the series are found in a very wild, almost uninhabited country, destitute of roads and consisting of flat-topped hills covered with forest, and intersected by deep gorges. There has hitherto been no opportunity of mapping the sub-divisions in detail, and no attempt has been made at separating them in the map.

The rocks referred to the Kámthi and Mahádeva groups occupy nearly two-thirds of the area of the field, including, with the exception of the small strip of Tálchirs (and in one case Barákars) already mentioned, all the western half, or rather more than half. The upper beds also occur in some small patches along the northern boundary, the principal of which is a hill, called Konjiri, on the Bráhmani north of Tálchir.

No trap-dykes have been found in the Tálchir basin; it is probable that this country is beyond the area affected by either Rájmahál or Deccan outbursts.

Outliers of Talchir beds in Mahanadi valley.—A few very small outliers of Tálchir beds have been found to the south of the Raigarh and Hingir field; and it is probable that the number may be increased when the ground is carefully surveyed. The only importance of these outliers is the indication they afford that the beds of the Gondwána system formerly covered a wider area.

Of these outliers[1] three occur near the Ebe river or upon its banks about 10 miles north-west of Sambalpúr. None of these exceeds a square mile in dimension. A fourth is found just south of the Máhánadi and opposite to the junction of the Ebe. Another is met with about 40 miles farther south on the Paljor river, a tributary of the Ong; and yet another exposure of Talchir beds has been noticed on the Tel river, about 80 miles south of Sambalpúr.

V. Satpúra region.—In the preceding pages of the present chapter the belt of Gondwána rocks has been traced south and south-east from the great central area in the valley of the Son to the basins of the Máhánadi and Bráhmani in Orissa. It is now necessary to return to the Sátpúra range stretching westward from the neighbourhood of Sohágpúr in the upper Son valley, the area intervening between the two regions of Gondwána rocks being covered by the basaltic lava

[1] Ball, Rec. G. S. I., X, p. 172.

flows of the Deccan trap. In the western or Sátpúra region the relations between the Gondwána beds and the surrounding rocks are very different from those which are so generally seen elsewhere. Instead of merely occupying basin-shaped depressions in the older formations, the Gondwána formations occur in the Sátpúra hills as a vast inlier exposed by denudation and surrounded on all sides except the north, and for some distance on the south, by bedded volcanic rocks of later date.

The Narbada valley is a great undulating plain, chiefly covered by post-tertiary deposits, beneath which, in places, the older rocks are exposed. These are, in almost all cases, metamorphic or transition. To the north of the broad alluvial valley is a range of hills formed of Vindhyan sandstones capped with trap. To the south the ranges are formed of the Gondwána series, also capped by trap. East of Hoshangabád, the rocks of the latter series are nowhere known to extend to the north of a line drawn along the northern base of the hill range. Further west, however, a few representatives of the highest Gondwána group have been found to the north of the river, though still in the valley itself.

In the present section the following tracts will be described :—

1. Sátpúra basin.
2. Upper Tapti area.
3. Small areas on the lower Narbada, west of Hoshangabád.

I. Satpura basin.—The Sátpúra coal basin[1] derives its name from the great range of hilly country lying south of the Narbada valley and separating the drainage area of that river from those of the Taptí to the west and the Godávari to the east. The range is known under various names, one of which is Sátpura. The area occupied by the Gondwána rocks may be considered as extending from the neighbourhood of Jabalpur to Lokartalai, south by west of Hoshangabád, a distance of between 170 and 180 miles, but the little tract near Jabalpur appears to be completely cut off from that to the westward by the overlying volcanic rocks, which, west of Jabalpur, overlap the sedimentary beds, and project to the northward, until they rest upon the metamorphic rocks of the Narbada valley. The Jabalpur tract is, however, scarcely worthy of separate notice; it is entirely composed of upper Gondwána beds (Jabalpur group) and extends for at least 25 miles, with one interruption near

[1] For detailed descriptions by Messrs. J. G. and H. B. Medlicott, see Mem. G. S. I., II, pp. 97-267; X, pp. (133)-(188) and Rec. G. S. I., III, pp 63-70, and VIII, pp. 65-86. The distribution of the Gondwána groups on the maps published in the second volume of the Memoirs has since been ascertained to be erroneous, though the boundaries of the coal-field are, as a rule, accurately laid down, except on the Pench river.

Lameta Ghât, along the edge of the traps which cover all the country to the southward. The beds exposed consist chiefly of the usual lavender grey and white clays, and earthy sandstones, usually soft, but occasionally much indurated. They appear to rest in places on the metamorphic rocks, and in places to be faulted against them. Some coal is found in the Jabalpur group at Lameta Ghât on the Narbada; the seam is of small thickness and irregular, and the coal has the usual peculiar structure, resembling that of jet.

Another similar belt of upper Gondwána (Jabalpur) beds extends upward of 20 miles along the edge of the trap country east and south-east of Narsingpúr. It is broader than the tract near Jabalpur, as it runs in some places for 5 or 6 miles up the valley of the Omar, Sher, and other rivers, which cut deep gorges out of the overlying volcanic rocks. The beds exposed consist of conglomerates at the base, succeeded in ascending order by soft shales, some of them carbonaceous and containing bands of jet coal, which are in places nearly 2 feet in thickness, but generally much thinner. Resting upon the shales are coarse sandstones and grits, which probably represent the Bandúgarh sandstone of the South Rewah basin.[1]

The Sátpúra field proper may be considered as commencing on the eastward nearly due south of Narsingpúr, and as extending thence to Lokartalai, a distance of about 110 miles, whilst the greatest breadth at right angles to the above is nearly 40 miles. The Gondwána area is broadest to the eastward, where, however, it is greatly covered by trap; it contracts rapidly to the west of the Tawa valley.

Divested of its covering of volcanic rock, this tract would probably exceed 2,500 square miles in extent, without taking into consideration its extension to the eastward; the area of Gondwána rocks actually exposed is, however, less than 2,000 square miles. The greater portion of this region is drained by the valleys of the Hard and Sákar, Sitariva and Dudhi, all tributaries of the Narbada, to the eastward; whilst to the west a number of streams, the largest of which is the Denwa, unite to form the Tawa, the largest stream which joins the Narbada west of Narsingpúr. The south-eastern portion of the area, however, is not in the Narbada basin at all, but south of the watershed, and it is drained by the Kanhán and the Pench, both of which run south toward Nágpúr, and there unite with other streams to form the Wain Ganga, which joins the Godávari.

The general geological relations of the Sátpúra field resemble those

[1] On the published map there is some confusion between these sandstones and the Lametas which were at the time supposed to be the equivalents of the Mahádevas.

of other Gondwána areas in this respect, that there is a general dip across the field (in this case, as in South Rewah, from south to north), the lowest beds being chiefly exposed near the southern boundary, and that the northern boundary is, on the whole, very nearly a straight line. But it has been shewn that the upper Gondwána rocks in places overlap this line and rest upon the metamorphic rocks to the northward, and it has consequently been suggested that the original survey of the field was erroneous, and that the northern boundary is not a line of fault. It must, however, be remembered that the lower Gondwána rocks are nowhere known to overlap the boundary line; that there is good evidence in Bengal for believing that great disturbance took place after the consolidation of the lower Gondwána beds and before the deposition of certain upper Gondwána groups; and that it is quite possible that the main northern boundary of the Sátpúra basin may be along a line of fault affecting only or chiefly the lower Gondwána beds. It was clearly shewn in the original account of the Sátpúra basin [1] that the supposed line of fault bounding the Damúda beds to the north is distinct from that forming the northern limit of the Mahádeva series, and it is also shewn that the boundary of the latter is occasionally natural. It is true that some of the data upon which these views were formed may need slight modification, but there is still a probability that the general conclusion is correct.

The area north of the field being thickly covered with the gravels and other alluvial deposits of the Narbada valley, it is impossible to say that the lower Gondwána rocks do not occur in places; but judging by other Indian coal-fields, it is improbable, and hitherto all attempts to find them have proved a failure.

The northern portion of the field consists chiefly of great sandstone plateaus, composed of the sub-divisions of the Mahádeva formation. Towards the east and west these plateaus terminate to the northward in scarps, 800 to 1,000 feet high, overlooking the alluvial plain of the Narbada valley. The central portion of the field is composed of the mass forming the Pachmarhi or Mahádeva hills, rising to an elevation of 4,380 feet, and consisting of the typical Mahádeva (Pachmarhi) sandstone. The southern portion of the field is less hilly, being composed of lower Gondwána rocks, but these appear at a considerable elevation to the south-eastward on the top of the watershed between the Narbada and Godávari drainage, and in the high upper valleys of the Pench and Kanhán, whilst to the westward they occupy the much lower ground of the upper Tawa valley.

[1] Mem. G. S. I., II, pp. 231, 237, &c.

The following are the groups exposed in the Sátpúra basin, and their approximate thickness where most fully developed :—

UPPER GONDWÁNA—		
	Jabalpur group	? 1,000
Mahádeva series—		
	Upper—Bágra group	800
	Middle—Denwa	1,200
	Lower—Pachmarhi	8,000
LOWER GONDWÁNA—		
Damúda series		
	Upper—{ Bijori group	4,000
	Upper—{ Motúr "	? 6,000
	Lower—Barákar group [1]	? 500
Tálchir group		1,000

The thickness of the Damúda groups is considerable, but has not been accurately determined.

It is quite unnecessary to describe these different groups in detail here, as a description of each of the Mahádeva and upper Damúda sub-divisions has already been given in the general account of the Gondwána series. All that is now requisite is chiefly to point out the distribution of the various groups within the area of the coal-field.

The Tálchir beds, consisting of the usual sandstones and clays, with boulders, occur continuously along the southern boundary. In some places, as at the head of the Tawa valley, south of Motúr, they are very thick, and are peculiarly well exposed on the hill sides. They are also found in several places along the northern boundary, always greatly disturbed and often faulted, their mode of occurrence being somewhat obscure. They are thus seen, beginning to the eastward, at Nibhora, west of the Hard river, where Bágra beds rest upon them; at Mopáni on the Sitariva, where they are associated with Barákars; in the gorge of the Anjar, above Fatehpúr; in the Amádi stream, near Bargandi; and around Ahoni on the Kukurkhadi stream, north of Pachmarhi. Except at Mopáni, the overlying rocks in all cases belong to high Mahádeva horizons, and are of course quite unconformable. In the upper Tawa valley the line of division between Tálchirs and Barákars is less marked than usual, the two groups appearing to pass into each other.

The Barákar is the only group in which useful coal has hitherto been found. Like the Tálchirs it is chiefly exposed near the southern boundary. It occupies a considerable area in the upper Tawa valley and in the Kanhán and Pench valleys; it presents the usual appearances and consists

[1] Whilst these pages were passing through the press, Dr. Feistmantel ascertained that a portion at least of the rocks hitherto classed as Barákars in the Sátpúra region belongs to the Karharbári group.

of felspathic brown, grey and whitish sandstones, flaggy beds, shale and coal. The coal seams in the upper Tawa are thin and, as a rule, inferior; they are, moreover, very irregular in thickness. There is much more coal in the Pench valley, and many of the seams are of considerable thickness and of fair quality; but the distance from all roads and the very hilly and difficult nature of the country to the northward have hitherto prevented this coal from being worked.

There is only one locality in which the Barákars[1] appear near the northern boundary; this is at Mopáni on the Sitariva, where they are much disturbed and tilted, Tálchirs appearing at the axis of a sharp anticlinal fold,[2] to the north of which the Barákars dip sharply; northward these are succeeded by Mahádevas with the same high dip; and the latter are covered up and concealed by the alluvium of the Narbada valley. All the Gondwána rocks are excessively crushed in this direction, and they are probably close to the boundary of the field, but no other rocks are seen, though both to the east and west metamorphic rocks come to the surface along the edge of the alluvium. An attempt to bore to the northward proved the alluvial deposit to be at least 491 feet thick. At this depth the boring was suspended, no hard rock having been reached.

To the south of the anticlinal the dip is lower, and there is much less crushing than to the northward. Three seams of coal occur, one 12 feet, the second 18, the third 14 feet thick, 2 feet of the last named being, however, shale; these seams have been worked for some years past by the Narbada Coal and Iron Company. The quality of the coal is fair, but not equal to the best coals of Bengal. The Barákars are faulted against Mahádeva beds belonging to the Bágra group just south of the colliery, and Mahádevas also cover the Barákars, close by to the eastward, and again at a distance of between 6 and 8 miles to the westward, the intervening ground being much concealed by alluvium. Altogether the little area of lower Gondwána beds about Mopáni has much the appearance of being brought up between two east and west faults.

The Motúr beds consist of sandstones, white or brown, with bands of red clay and some nodular limestone, and much resemble the Panchets of Bengal. The Bijori rocks are more like ordinary Damúdas, and comprise felspathic sandstones, flaggy beds and shales, sometimes earthy, grey or brown, and occasionally carbonaceous. No coal has been found in these beds. The area of these two upper Damuda groups is in the

[1] Probably Karharbáris: see note on last page.
[2] See Rec. G. S. I., III, p. 63.

great flats and hill ranges drained by the Tawa and its tributaries and lying south of the Pachmarhi range. They here occupy a large tract of country upwards of 50 miles in length and 20 in breadth where widest.

The lowest portion of the Mahádeva group consists of the thick massive sandstones and grits of the Pachmarhi hills. These are well seen in massive, nearly horizontal beds, along the scarp forming the southern face of the range. The Pachmarhi group is traced for some 60 miles from east to west, and its outcrop is, where widest, 12 miles across; but it is evident that the group is thickest here, and that it gradually thins out in both directions. How far this thinning out is due to replacement by beds having the lithological characters of the upper Mahádeva groups, and to what extent it is due to a difference in the amount of sediment deposited in neighbouring areas, is less clear: in places to the eastward the former certainly appears to be the case.

The Denwa group shews some repetition, at a much higher horizon, of the conditions which prevailed during the deposition of the Motúr sub-division of the Damúdas, and consists principally of pale greenish yellow and bright red mottled clay with subordinate bands of sandstone and some thin beds of limestone. This group is chiefly developed north of the Pachmarhi hills; it is overlapped to the west, but continues for a long distance to the eastward, though its appearance is less typical than in the Denwa valley.

To the Denwa group apparently must be referred the rocks seen in the Moran river, near Lokartalai, in the extreme north-west of the field. These beds consist of sandstones, shales (some of which are carbonaceous), and a seam of inferior shaly coal, about 4 feet in thickness, but apparently worthless for fuel. Some other coal seams have been proved to exist by boring, but none appear to be of value. The Denwa beds are brought up by an anticlinal, and are apparently only exposed for a short distance in the immediate neighbourhood of the stream. These beds were formerly referred to the Damúdas, but the discovery in them of *Ptilophyllum acutifolium* and *P. cutchense* has shewn that they must be referred to an upper Gondwána horizon.

The Bágra group is chiefly conglomeratic,—sandstones, limestones, and clays being of less importance. It extends almost throughout the northern edge of the field.

The Jabalpur group is chiefly found to th eeastward; it forms nearly the whole of the sandstone area north of the trap and east of the Dudhi valley, but west of that river it is only represented by outlying patches. The most western of these outliers is at Chátar hill, a little west of the

Dudhi river. There is, however, an outcrop of whitish sandstone with white shale and pyritous coaly shale resting on the Bágra group near Zumáni, nearly due south of Hoshangabád, and this exposure appears also to belong to the Jabalpur horizon.

Trap-dykes abound throughout the whole area, many of them being of large size, and in places irregular intrusions of trap have a tendency to run horizontally between the layers of bedding. This is chiefly the case amongst the beds of the upper Gondwána series, and especially in the Jabalpur group.

2. **Upper Tapti area.**—This tract is entirely outside of the Narbada valley, and is situated on the head waters of the Tapti. It lies, at an elevation of 1,500 to 2,000 feet above the sea, on the plateau which forms the watershed of the Sátpúra range, and extends along the edge of the traps, intervening between them and the underlying metamorphics, throughout a considerable area west and north-west of Betúl.[1] The boundary of the volcanic rocks is here very tortuous, and forms a series of curves, owing to the irregular action of denudation. The sandstones and conglomerates between the traps and the metamorphic rocks vary greatly in thickness; throughout a considerable tract they appear not to exceed 100 feet, and they are often thinner. The bed in this case is conglomeratic and sometimes cherty, and it appears to belong to the Lameta group. But near the villages of Alampúr, Khettapáni, and Khamapúr, 25 to 30 miles west by north of Betúl, and again in the Tapti river about the same distance west of the station, soft red argillaceous sandstones, with harder bands, and occasionally with red shales or clays, are exposed, much resembling some of the Mahádeva formations, and probably representing a portion of the Gondwána series. No fossils have, however, been found in these beds.

3. **Areas on Lower Narbada, west of Hoshangabad.**—For some distance west of Lokartalai, where the Gondwána rocks of the Sátpúra field disappear beneath the Deccan traps, there is, along the southern edge of the Narbada valley, and at the base of the hills which occupy the country to the south, a line of disturbance in continuation to the south-westward of that seen along the northern boundary of the Sátpúra field. Along this line of faulting the volcanic layers are turned up sharply and dip to the south. From beneath them, here and there, small outcrops of sandstone appear, evidently belonging by their characters to the Bágra group of Mahádevas. The best exposure is in the Ganjál stream, 6 or 7 miles west of Lokartalai. Sandstones are traced

[1] Mem. G. S. I., VI, pp. (272)-(275).

at intervals for 4 miles further, and the line of disturbance continues for 25 miles.

Close to Barwai on the Narbada, about 100 miles below Hoshangabád, and 80 or 90 west by a little south from Lokartalai, some coarse conglomerates, with a matrix of clay, occur beneath another conglomeratic band containing oyster shells: the latter, which belongs to the cretaceous Bágh beds, being unconformable to the other. The lower conglomerate has now been recognised[1] as Mahádeva, and this recognition renders it probable that some of the other sandstones of the lower Narbada valley belong to the same formation. The Mahádevas of Barwai are of small thickness and rest on Bijáwar rocks. No trace of Damúdas can be detected.

Somewhat similar conglomeratic beds to those of Barwai have been traced, at intervals,[2] throughout a considerable area to the eastward, between Barwai and Hindia, intervening between the base of the traps and various older rocks, Vindhyan, Bijáwar, or metamorphic. These conglomerates, however, appear to be, as a rule, of later date than the Mahádevas, and to represent the Lameta group. Still, further examination will be necessary to test the presence or absence of Mahádeva outliers. In one case, at Bhorla, near Punássa, south of the Narbada, these conglomerates appear with nodular grey limestone resting upon them. The latter is probably a representative of the Bágh beds: the conglomerate may be Mahádeva. In this case the underlying rock is not seen.

West of Barwai the Narbada valley is entirely composed of trap for about 50 miles; beyond this distance inliers of metamorphic and Bijáwar rocks reappear. Around Bágh[3] there are several such inliers, and in all of them fossiliferous cretaceous beds, resting upon sandstones, intervene between the traps and the old crystalline rocks. The sandstones thin away to the northward, but become much thicker to the south. They occupy a considerable tract between the traps and the metamorphic rocks west of Bágh, but they gradually thin out again and disappear along the southern edge of the great metamorphic region of Chota Udepúr farther to the west. The great tract of metamorphic rocks extends westward to the neighbourhood of Baroda, whilst the valley of the Narbada to the southward is formed of trap, in which inliers of the sandstones, with the calcareous Bágh beds resting upon them, are exposed in places through denudation. There are several such inliers south of Bágh,[4] some others south of Chota Udepúr,[5] and the largest is south of

[1] Rec. G. S. I., VIII, p. 73.
[2] Mem. G. S. I., VI., p. (217).
[3] *Ib.*, pp. (211), (212), (307), &c.
[4] Mem. G. S. I., VI., p. (310).
[5] *Ib.*, p. (323), &c.

the Narbada, on the Deva stream, at the boundary between the small states of Rájpipla and Akráni. This inlier[1] is about 10 miles across from east to west and nearly as much from north to south. Below the traps are about 500 feet of calcareous shales belonging to the cretaceous formation, succeeded in descending order by sandstones and conglomerates, of which at least an equal thickness is exposed. There is apparent conformity between the two, and both tend similarly to increase in thickness to the southward. It is far from impossible that the sandstones may represent the Mahádeva formation.

Similar sandstones again occupy a considerable tract north-west of this Deva inlier and south-west of Baroda, at the edge of the alluvium of Gújrat. In no case has a trace of any lower Gondwána rock been detected in the lower Narbada valley; the conglomerates and sandstones, just mentioned as possibly of Mahádeva age, in this region, where their base is seen, rest upon the transition beds or gneiss, without any intervening band of Tálchir or Damúda rock. The country has not yet been examined sufficiently closely to prove the absence of lower Gondwána beds, and it is possible some may occur beneath the sandstones of the Deva valley, but it is extremely improbable that, if they do, no trace of them should have been detected in the numerous localities from Bágh to the neighbourhood of Baroda, in which the sandstones beneath the Bágh beds are seen resting upon older formations.

[1] Mem. G. S. I., VI, p. (347), &c.

CHAPTER X.

PENINSULAR AREA.

GONDWÁNA SYSTEM—*continued*. DETAILS OF GONDWÁNA BASINS.

VI. GODÁVARI REGION — 1, Inliers near Ellichpúr — 2, Inliers west and north-west of Nágpúr — 3, Kámthi area — 4, Bandar coal-field — 5, Outliers near Khair and Arjuna, south of Wún — 6, Wardha-Pránhita-Godávari basin — *a*, Wardha (Chánda) coal-field — *b*, Central portion — *c*, South-eastern extension to neighbourhood of Ellore and Rájámahendri — 7, Kamáram coal-field — 8, Singareni coal-field. VII. EAST COAST REGION — 2, Athgar — 3, Outcrops east of Rájámahendri — 4, Ellore — 5, Ongle outcrops — 6, Sripermatúr outcrops — 7, Trichinopoly or Utatúr.

VI. GODÁVARI REGION.—The area occupied by Gondwána formations in the Godávari valley is probably greater than in the drainage area of any other river. The name Godávari is restricted above Sironcha to the southern affluent of the river, but the northern branch, known as the Pránhita, and formed by the union of the Pen Ganga, Wardha and Wain Ganga, is equal in size to the main stream. The great Godávari belt of Gondwána rocks extends from a few miles south of Nágpúr, through the plains of the Pránhita and Godávari, to the coast alluvium in the neighbourhood of Ellore (Yelaur). A great part of this area is but imperfectly known, and only a few tracts have received more careful examination. It will be necessary to describe these tracts separately.

A detached area occurs at the edge of the trap region close to Nágpúr, and inliers are exposed within the trap boundary west and north-west of Nágpúr, and again near Ellichpúr in Berar. The latter localities are beyond the Godávari watershed, but it is best to consider them in connexion with those included in the latter, as they are intermediate between the Sátpúra fields and those of Nágpúr. Other outliers occur further to the south and south-east, and doubtless more remain to be discovered.

The following areas will be noticed under this general heading:—

1. Inliers near Ellichpúr.
2. Ditto west and north-west of Nágpúr.
3. Kámthi area.
4. Bandar coal-field.
5. Outliers near Khair and Arjuna south of Wún.

6. Wardha-Pránhita-Godávari basin.
   a.—Wardha coal-field.
   b.—Central portion from third to first barrier of the Godávari.
   c.—South-eastern portion from first barrier of the Godávari to the neighbourhood of Ellore and Rájámahendri.
7. Kamáram coal-field.
8. Singareni coal-field.

1. Inliers near Ellichpur.—Along the southern scarp of the great spur, which, separating from the Sátpúra range near Betúl (Baitool) and extending from east to west between the valley of the Tapti and that of its great affluent the Púrna, is known by the name of the Gawilgurh (Gáwelgarh) hills, there is, north and north-east of Ellichpúr, a line of fault, running east-north-east to west-south-west, and having a considerable downthrow to the south. Along the northern or upthrow side of this fault, sedimentary beds appear, in places, from beneath the Deccan traps forming the whole of the surrounding country, and extend for a considerable distance—in one case for several miles—along the base of the hills. These exposures are but 30 miles south-south-east of the sandstones in the Tapti west of Betúl.

The most western of these inliers occurs about 8 miles north of Ellichpúr, and extends east and west between 6 and 7 miles. For 16 miles to the eastward no sedimentary rock is seen in place, but in one spot, 3 miles west of Narha, some blocks of sandstone occur, and there may be a small outcrop. At Narha, about 22 miles east by north of Ellichpúr, the sandstones reappear north of the fault, and extend for 15 miles. They then disappear again, but two smaller inliers, each about a mile long, occur at short intervals just beyond.

In these inliers Lameta (cretaceous) beds occur immediately beneath the basaltic traps, and are succeeded in descending order by about 500 feet of strata comprising felspathic sandstones, white and brown conglomeratic beds, occasional ferruginous beds, and thin layers of white and purple shale. It has not been decided whether these rocks are of Kámthi age or whether they should be referred to the Mahádeva series, no distinguishable fossils having been found.

No beds of Barákar or Tálchir age have been detected, and the base of the sedimentary beds is not seen, whilst an attempt to discover coal by boring proved unsuccessful. Metamorphic rocks appear in one place along the southern edge of the sandstone, and are apparently brought up between two faults with their throws in opposite directions. As these faults coincide at each end of the strip of metamorphics, there is evidence in this instance of two throws in opposite directions having taken place along the same line of weakness.[1]

[1] For further details see Mem. G. S. I., VI, pp. (277)-(283).

2. Inliers west and north-west of Nagpur.—These inliers are about 30 miles east of the last mentioned, and are three in number.[1] Two occur close together near the villages of Chorkheri and Kútkheri, about 30 miles north-west of Nágpúr; the third near Bazárgaon, about 20 miles west of Nágpúr.

The Chorkheri inlier is only 4 miles in diameter from north-west to south-east and 3 miles broad. That of Kútkheri lies 1½ miles to the south-east of the other, and is only a mile in length. The Bazárgaon inlier is 10 miles from east to west, and 5 from north to south. The only beds exposed in any of these inliers belong to the Kámthi group. The existence of these patches of sandstone proves that similar beds in all probability underlie the traps in this part of the country over a considerable area.

The only rocks found are coarse, gritty, felspathic sandstones and occasional bands of hard compact shale, red or yellow in colour. In the Bazárgaon inlier some of the sandstones are conglomeratic. No trace of Barákar beds has been detected in these inliers.

3. Kamthi area.—Immediately north of the town of Nágpúr, a small tract of Gondwána rocks appears at the edge of the trap area,[2] and extends from the village of Kámthi, whence the military cantonment of Nágpúr derives its name, to the small town of Kelod, a distance of rather more than 25 miles from south-east to north-west; the greatest breadth of the tract at right angles to the above is 9 miles. The north-eastern boundary appears to be straight or nearly so, and is probably a fault, but it is ill seen throughout the greater portion of its length. Beyond it to the north-east the country is composed of metamorphic gneissic rocks, but both the gneiss and the sandstones are greatly concealed by alluvial deposits of considerable thickness. The south-eastern boundary appears to be natural and tortuous, metamorphic rocks appearing just beyond it in several places. To the west and south the sandstones disappear beneath the Deccan trap. The area occupied by sedimentary rocks of the Gondwána series somewhat exceeds 100 square miles.

This tract of sedimentary beds has long been known, having attracted attention from being in the neighbourhood of a large town, and from some of the fossiliferous beds being extensively quarried. The area has moreover been exceptionally fortunate in having been thoroughly explored by the late Mr. Hislop. The only groups represented are Tálchirs and Kámthis.

[1] Mem. G. S. I., IX, p. (313).

[2] For fuller description, see Mem. G. S. I., Vol. IX, pp. (295)-(330).

The Tálchirs are represented only in two places. The first of these is near a village called Korhádi, about 6 miles north of Nágpúr, where some reddish and olive-grey shales occur in streams just east of the road from Nágpúr to Chhindwára. These shales contain large rounded boulders of metamorphic rocks and of the characteristic Vindhyan quartzite-sandstone and limestone. The Vindhyan fragments are probably derived from a considerable distance, as no outcrop of this formation is known near Nágpúr. The other Tálchir locality is a small isolated hillock known as Koda Dongri, which is surrounded by alluvium, and lies on the edge of the sedimentary tract north of the village of Pátan Sáongi, 14 miles north of Nágpúr. The hillock consists of vertical beds, apparently of Tálchir age.

The Kámthi beds are here seen in their typical locality, and are composed of the rocks already mentioned when describing the group as a whole. They occupy the whole area of sedimentary beds, with the exception of the two minute patches of Tálchirs specified above. They are well seen at Kelod, again south of Sáoner, and also south of Pátan Sáongi, and along the edge of the traps from Tondakheri to Bhokára north of Nágpúr; but the best known exposures are at Silewára, 9 miles north of Nágpúr, and Kámthi. At both of these places large quarries exist, from which numerous fossils have been obtained. The most characteristic beds are the coarse felspathic sandstones, brown, red, or white in colour, with bands of hard ferruginous grit, and the compact yellow and red shale. There is not a trace of carbon left in the plant fossils, and as the Barákars appear to be completely absent in the area, there is no probability of any coal occurring.

4. **Bandar coal-field.**—Around the town of Chimúr, about 30 miles north-east of Warora in the Chánda district, a considerable tract of Tálchir beds is exposed, resting to the east and west on metamorphic rocks, and to the south and south-west on Vindhyans, whilst to the north and north-west it is covered by the Deccan trap and infratrappean Lameta beds. This Tálchir area is about 18 miles in extreme length from north to south, and about 10 miles broad.

In the north-western corner, a few miles north-west of Chimúr, there is a small tract, of triangular form, occupying about 5 to 6 square miles, and composed of Kámthi beds resting upon Barákars. This small area has received the name of the Bandar coal-field.[1] The Damúda beds are covered by infratrappean beds to the north, but elsewhere rest upon the Tálchirs, and they occupy the axis of a synclinal

[1] For a full account by Mr. Hughes, see Mem. G. S. I., XIII, pp. 145-154.

basin. The Kámthis overlap the Barákars to the north-east, but the latter underlie the greater portion of the field, their presence having been proved, throughout a square mile, near the village of Bandar, by borings.

The character of the rocks differs in no respect from that in the neighbouring Wardha field. A maximum thickness of 38 feet of coal has been proved, divided into three seams. The quality appears to be much the same as that of the Warora coal.

5. Outliers near Khair and Arjuna.—Before proceeding to the description of the main Gondwána area in the Godávari valley, it is desirable briefly to notice some outliers to the west of the northern portion. Near the village of Khair, about 25 miles west of Chánda a considerable area of sandstone is found extending for about 5 miles up a valley between low hills of Deccan trap. Similar sandstone, greatly hardened, is again seen to the south, in the Yedurba stream, which is chiefly supplied by a copious hot spring close to Khair. Two other small outcrops separated by overlying trap are met with about 2 miles further to the south-west near the small village of Kasara, and a larger tract of irregular form, about 4½ miles from east to west and 3½ from north to south, occurs still further to the south-west, around the village of Arjuna, 9 miles south-west of Khair. All these outcrops are covered by trap to the north-west. The beds are very ill seen, but appear to rest on Vindhyan limestones to the east and south.

In places the beds of these outcrops are so greatly indurated that it was at first considered doubtful whether they could be referred to any known formation. This is especially the case with the rocks on the Yedurba stream and near Arjuna. The beds in the valley north-west of Khair have, however, the usual characters of Kámthis, and the discovery by Mr. Hughes of Tálchirs at the southern extremity of the Arjuna outcrop has shewn that all the rocks must belong to the Gondwána series. No exposure of typical Barákars has been detected, but the occurrence of this group is highly probable, and should coal be required in the neighbourhood, the exploration by boring of these areas near Khair will become necessary.

6. Wardha-Pranhita-Godavari basin.—*a. Wardha or Chánda coalfield.*—The large area of Gondwána rocks in Chánda and South-East Berar has received much attention of late years on account of the exertions made to procure from it a supply of coal for parts of the Great Indian Peninsula Railway. It is the north-western extremity of an immense tract of Gondwána rocks extending for about 285 miles from north-west to south-east, and with a maximum

breadth of about 35. This north-western portion having been carefully examined,[1] deserves a notice apart from the large but less thoroughly known region on the Pránhita and Godávari. The Chánda and Berar area derives its name from the river Wardha, which traverses it throughout, and forms its southern boundary, an artificial but convenient limit, at the point where that river, after running south-east or south for many miles, turns eastward and runs for about 20 miles with a general direction a little north of east till it joins the Wain Ganga. The Gondwána area is at this spot much narrower than it is to the north and to the south, being only about 14 miles broad from east to west.

The tract to the northward of this artificial boundary is about 70 miles in length from north-west to south-east, and nearly 30 broad where widest; extending to the north-west to within 15 miles of Hinganghát: the area is about 1,600 square miles. The field may be considered as a trough lying between two great parallel faults which run from north-west to south-east, one forming the north-eastern boundary of the field from end to end, whilst the other only forms the actual boundary where the field is broadest about Wún and Chánda; the latter dies out to the south-east and disappears to the north-west beneath the trap. The Gondwána rocks, where most developed in the neighbourhood of Chánda, exhibit an anticlinal fold, much nearer to their south-western than to their north-eastern limit, and they dip on each side of this fold towards the boundary. Along the axis of the anticlinal, Vindhyan beds crop out in places, and to the northward divide the Gondwána area into two arms, each running north-west along one of the boundary faults till the whole is covered up by the trap. To the south, as already mentioned, the south-western boundary fault appears to die out and the area assumes the normal form of a mass of rocks, dipping steadily at a low angle to east-north-east, and abruptly cut off in that direction. The area to the south-west of the Gondwána tract is chiefly composed of shales and limestones belonging to the lower Vindhyan series (Pem shales and limestone), and inliers of these rocks are exposed here and there within the limits of the Wardha field. To the north-east and east metamorphic rocks are chiefly to be found, except for about 20 miles north-east of Chánda, where the Gondwána rocks abut against Vindhyan quartzites. Every here and there, however, along the north-eastern boundary fault, masses of Vindhyan quartzite or limestone are found, some of them apparently faulted on both sides to the westward

[1] The account is taken from a description by Mr. Hughes, Mem. G. S. I., XIII, pp. 1–145.

against the Gondwána beds, to the eastward against the metamorphics. The southern boundary of the Wardha field, as already mentioned, is artificial; to the north-west all the older formations, metamorphic, Vindhyan, and Gondwána, disappear beneath the overlying Deccan trap and the infratrappean Lametas.

The groups exposed in the Wardha field are the following:—

Upper Gondwána—Kota-Maleri	. . . . . .	about 1,500
Lower Gondwána.	Kámthi	2,500 to 3,000
	Barákar	250
	Tálchir	? 500

The Tálchirs occupy a large area, altogether amounting to about 250 square miles, and must be of considerable thickness. Immediately west of the town of Chánda they cover a tract of country extending more than 20 miles from north to south by 14 broad, part of the area, however, being concealed by river alluvium. They also stretch for about 15 miles along the south-western edge of the Wardha field, in the Nizam's territory, south of Rajúr, and they are found forming a narrow fringe on the north-eastern edge of the western arm of the field north-west of Wún.

The mineral character of the Tálchirs is, as a rule, precisely the same as elsewhere. The upper beds are buff sandstones, often with a greenish tinge, and a tendency to break up into polygonal fragments. These sandstones pass downwards into greenish-grey (olive) silty shales, with or without sandy layers, and in these shales, especially towards the base, boulders are common. In one locality, at Irai, on the banks of the Pen Ganga (Pem or Pyne or Pain Gunga) river, not quite a mile above its confluence with the Wardha, Mr. Fedden had the good fortune to discover[1] boulders which exhibited polishing and grooving on their surface, whilst the underlying rock, consisting of Vindhyan limestone, was extensively scored, grooved, and polished, the striæ running in long parallel lines with a north east by north direction. Some flexible sandstone (quartz grains in an argillaceous matrix) has also been found in the Tálchir beds south of the Pen Ganga.

The Barákars are very thin, nowhere exceeding 250 feet in thickness, and they are often less than this. Their general descending section is—

1. A very thick seam of coal and carbonaceous shale
2. Sandstones and shales.
3. A few thin carbonaceous beds.
4. Sandstones and shales.

[1] Mem. G. S. I., IX, p. (234): Rec. G. S. I., VIII, p. 16.

The sandstones alone being, as a rule, seen at the surface; they are usually either fine-grained, light-grey beds, sometimes with specks of ferruginous quartz, iron pyrites, or carbonaceous matter, or else they consist of somewhat coarser beds, white, grey, or light brown in colour, containing little calcareous nodules, which weather out into small excrescences on the surface.

In some places sandstone belonging to the Barákars rests upon the thick coal seam, but over a very considerable area Kámthis appear immediately to overlie it. This seam is an irregular mixture of coal and carbonaceous shale, the proportions of the two varying in almost every one of the numerous bore holes by which it has been proved. As a rule, the greater portion consists of coal of rather inferior quality, some bands, however, being sufficiently good for steam purposes, while all might be used as fuel; the quantity of ash is generally large, varying from 14 to over 20 per cent. The thickness of the combined seam of coal and shale sometimes amounts to as much as 90 feet, but is more often between 35 and 50. Some thin seams, none of which are known to exceed 2 feet in thickness, are also found at a lower horizon.

The Barákars are most irregularly distributed in the Wardha field, being overlapped throughout a large area by the Kámthis. Owing to the mineral value of the Barákars, their extension has been carefully determined by boring. They appear in one spot about 6 miles north of Warora, but coal has not been proved here. It has, however, been found to underlie the alluvial ground near Warora, where a colliery has been established, and a large quantity of coal extracted. Barákars also occur, and coal has been found, in the bed of the Wardha near Aikona, 6 miles west-north-west of Warora. The dip here is south-west, and the coal doubtless extends under the trap to the southward.

The next tract of Barákars to the southward is along the arm of the field already described as extending north-west of Wún. Here the Barákars form a straight outcrop, about a mile broad, dipping south-west, and they have been traced for 8 miles from north-west to south-east on the surface, and 3 miles farther to the south-east by boring. They may be continuous with the area further east and south-east, extending for about 20 miles from west of Bhandak to the Pen Ganga west by south of Chánda, and containing the thick coal of Telwása, Ghúgús, &c. This belt of Barákars extends along the western edge of the Tálchir area west of Chánda, until, to the southward, the Barákars are overlapped by the Kámthis. The Barákars reappear, however, south-east of the Tálchir anticlinal, about Ballarpúr and Sásti, and are represented, though apparently but feebly, at Chánda itself, where the upper portion, including the

thick coal, is absent. They are completely overlapped by the Kámthis north of Chánda. The great tract of Kámthis east and south-east of Chánda has not been sufficiently explored by boring to ascertain whether Barákars underlie it or not.

One more tract of Barákar rocks extends for 12 miles along the south-western margin of the field from Sirsi, 7 miles south of Rajúr, to Antargáon on the Wardha, where that river turns to the eastward. South of Rajúr the Kámthis completely overlap the Barákars as far as Sirsi. Some coal occurs, but the thick seam has not been traced.

The Kámthis occupy all the eastern and north-eastern portion of the field, as well as a large tract in the north-western portion around Wún, and more than two-thirds of the whole surface is composed of them. They are unconformable to the Barákars as already mentioned, and overlap them in many places, resting generally upon the Tálchirs, but occasionally on the Vindhyans. Their mineral character is the same as near Nágpúr, except that they comprise in places beds of red, yellow, and grey clay.

At the base of the Kámthi group, the principal beds are coarse-grained, porous, friable sandstones, slightly yellow, reddish-brown, or grey in colour. The porosity of these beds generally enables them to be distinguished from the sandstones of the underlying Barákar group, even when the Kámthi beds are deficient in the ferruginous bands so frequently associated with them. These sandstones average 400 to 500 feet in thickness; the town of Chánda is built upon them, and they are well seen on the banks of the Wardha below the coal pit at Ghúgús, west of Chánda. Clays and shales are occasionally interstratified, but neither the argillaceous beds nor the hard irregular ferruginous bands are invariably found.

Above these lower sandstones, there is, in places, but not universally, a considerable thickness of the typical Kámthi beds, consisting of compact grits, breaking with a conchoidal fracture, and ringing under the hammer, fine-grained or coarse sandstones with red blotches and streaks upon a whitish, yellow, or brownish-red surface, very fine-grained compact homogeneous sandstones, having an argillaceous appearance, but apparently free from clay, buff in colour beneath the surface, but deep red when exposed, and ferruginous sandstones and conglomerates containing small quartz pebbles. On this horizon in the northern extremity of the field, and about 600 or 700 feet above the base of the group, are the beds of Mángli, from which the *Brachyops*, *Estheriæ*, and other fossils mentioned in the fifth chapter were obtained, and at approximately the same position in the group, about 16 miles due west of Chánda, around

Kawársa and Panwat, some fossiliferous beds were found, from which besides a form of *Estheria mangaliensis, Phyllotheca indica, Glossopteris indica, G. browniana,* and fragments of *Schizoneura* have been recognised.[1] In some shales near Chánda, also near the base of the Kámthis, fine fronds of *Glossopteris* have been found, and in another place some impressions referred to *Actinopteris;* but, as a rule, fossils are of rare occurrence in the Kámthi group of the Wardha coal-field.

The upper portion of the Kámthis consists of a great thickness of coarse sandstones, grits and conglomerates, with occasional shales and clays. The beds are usually more or less impregnated with iron, and sometimes are highly ferruginous: manganese is also of common occurrence, and in some red clays at Malágarh hill, west of Kawársa, botryoidal masses containing no less than 44·6 per cent. of oxide of manganese were found.

The upper beds of the group are usually poorly exposed; they occupy the wild forest country east and north-east of Chánda, sometimes rising into low hills, but more often covered and concealed by the thick sands and clays which result from their decomposition. A few outcrops are seen south of Wún, and in the Wardha below Chánda, but no connected section of the rocks is anywhere exposed. It is consequently impossible to estimate the thickness of the Kámthi group with accuracy.

The Kota-Maleri beds are only found north of the Wardha in a small triangular tract around the village of Dhába in the south-east corner of the Wardha field. This patch is the northern extremity of the great area which extends to Maleri and Kota, and thence to the south-east far beyond Sironcha. The greater part of the area is covered with alluvium, but on the banks of the Wardha, about Porsa, Enkatpúr, and Sakmúr, sections of the characteristic sandstones and clays of the group are seen. The Kota-Maleri group appears to be unconformable to the Kámthi beds; but the relations are ill seen in the small area north of the Wardha river.

No basaltic dykes are known in any part of the Wardha coal-field, nor have any hitherto been noticed elsewhere in the Gondwána area of the Godávari valley. This absence of all evidence of volcanic outbursts is very remarkable, because the Gondwána rocks disappear beneath the Deccan traps to the westward, and an outlier of the same formation is found at the south-eastern extremity of the whole tract near Rájámahendri.

Wardha-Pranhita-Godavari basin.—*b. Central portion.*—From the spot where the Wardha runs eastward to join the Wain Ganga, just

[1] Mem. G. S. I., XIII, p. 70.

above the so-called third Godávari barrier on the Pránhita, a stream formed by the confluence of the two other rivers, to within a few miles of Dúmagúdem (Doomagoodiam), at the first Godávari barrier, is a distance in a direct line of about 140 miles. A broad belt of Gondwána sandstones extends throughout, but the river does not keep within the boundary of the sedimentary rocks. The Pránhita, throughout the greater portion of its course, runs to the eastward of the sandstone area, and the main stream of the Godávari, which enters the sandstone some 30 miles above the junction with the Pránhita, re-enters the older rocks about 25 miles below the junction, just above the confluence of the Indrávati (Indrawutty) river. From this spot the Godávari runs through transition beds and metamorphics for nearly 20 miles, forming the portion of its course known as the second barrier: the river then re-enters the newer sandstone area, through which it runs till just above the first barrier at Dúmagúdem. The Gondwána rocks, however, nowhere extend far to the east of the Godávari, quartzites appearing below the second barrier at a short distance from the river bank.

This large area of sandstone is as yet but imperfectly known; the country is very wild and, for the most part, covered with forest, and the surface is much concealed by alluvial deposits.[1] From the Wardha coal-field the present tract is separated by the Wardha river, the separation being, as already explained, merely one of convenience, at a spot where the field of sandstone is unusually narrow. To the south-east the limit is still better marked, there being a great contraction in the breadth of the Gondwána area at Palúncha, 15 miles west-south-west of Bhadráchelam, where the sandstone tract is only 6 miles across, while to the north-west it is between 30 and 40 miles broad, and to the south-east seldom less than 25, and in places considerably more. The north-east and south-west boundaries of the intervening Gondwána area are nearly straight, and in general present an approximate parallelism.

A short distance south of the Wardha the sandstone area becomes much broader, and the western boundary thence to the Godávari is formed partly by Vindhyan (or Kadapah?) rocks and in part by the overlying Deccan trap, the sedimentary beds being exposed in one locality in a valley between ranges of trap hills. South of the Godávari the trap boundary leaves the Gondwána area and runs to the south-west, and by far the greater part of the Gondwána boundaries, both to the

[1] It is now under examination, and much additional knowledge of its structure has been obtained very recently. The following description is chiefly taken from manuscript reports by Messrs. King and Hughes.

north-east and the south-west, consist of Vindhyan or transition rocks. Throughout a considerable portion of the Gondwána region there is a low dip of the strata to the north-east, so that, as a rule, the lower beds are exposed along the south-western boundary, and high beds abut against the north-eastern margin of the field.

The greater portion of the area consists of coarse sandstone, more or less conglomeratic. The groups known to be represented are the Kota-Maleri beds, with some overlying sandstones (Chikiála group) which closely resemble a higher group in the Rájámahendri country, the Kámthi, Barákar, and Tálchir groups of the lower Gondwána series. Both of the latter, so far as is known, are confined to small and isolated tracts.

Tálchirs have hitherto been found in a few places only. Of these the most northern is just north of Náogáon about 12 miles south-west of Sirpúr. The area occupied is very small. The same beds, however, resting upon Vindhyans, stretch along the western boundary of the Gondwána area from Kairgura, south of Jangáon and 26 miles south-west of Sirpúr to the Godávari near Náspur, 22 miles west of Chinúr, and probably for some distance south of the river. The Tálchirs are again found close to Chinúr, overlying an inlier of Vindhyan rocks, both formations being brought up within the Gondwána area, in all probability, by a north-west and south-east fault. Throughout these exposures the typical Tálchir shales are rare, the group consisting chiefly of sandstone; but the boulder bed is well developed, the boulders consisting partly of Vindhyan, partly of metamorphic rock. In the country south-west of the Godávari the Tálchirs have been noticed around Sallawai (Sullavoy of the map), about 16 miles north by east of the great Pakhal tank and 36 miles north-east of Wárangal. Lastly, they are found in the Tál river, close to its junction with the Godávari, 16 miles north of Dúmagúdem, and extend for some distance to the south and south-east along the edge of the Gondwána area.

Barákars occur on the Wardha near Antargáon, where they form a continuation of the Chánda and Sásti coal-field, but they are covered up and overlapped by Kámthis to the south. They reappear about 10 miles farther south near Náogáon, but only occupy two or three square miles, and no coal has been hitherto detected in them. A more important outcrop extends from Kairgura, south of Jangáon, for about 25 miles in a south-east direction to the village of Aknapali. The breadth of the outcrop is not more than a mile, and the beds are ill seen as a rule, but sections of the typical sandstones occur in the streams, and a coal seam has been found in three places, the thickness

exposed varying from 5 to 15 feet. It is by no means improbable that this seam is continuous throughout the Barákar area. The quality of the coal appears to be fair, but hitherto the seam has not been cut into.

No Barákars have been detected resting upon the Tálchirs between Aknapali and the Godávari, a distance of about 16 miles, but it is not impossible that borings may shew the existence of the coal-bearing rocks. Near Chinúr and Sandrápali, however, beds of unmistakeable Barákar character rest above the Tálchirs, and fragments of coal found in the Godávari, below Sandrápali, probably indicate the existence of a seam concealed by the sand in the bed of the river. Barákars are again seen in the Godávari at the mouth of the Tál river near Dúmagúdem, and they extend thence for 4 miles to the south, whilst to the north they and the underlying Tálchirs appear either to be overlapped by the Kámthi beds or cut off by a fault. In this neighbourhood the Barákars are best seen about Lingála on the left bank of the Godávari. They have rather a high dip, and reappear on the opposite river bank in the Nizam's territories. Some coal occurs, but the thickest seam found measures only 2 feet.

Throughout the large tract south-west of the Godávari between Chinúr and Dúmagúdem, no Barákars have been found away from the river's bank, although they very probably are represented by some coarse sandstones at Sallawai resting upon the Tálchirs already mentioned, and an outcrop must exist at Alapali on the Kinerswámi (Kinarsani) stream, 30 miles west of Dúmagúdem, as numerous fragments of coal are found in the bed of the stream.

The Kámthi beds occupy a great portion of the area, and appear to stretch uninterruptedly from end to end. They must be very thick[2]; the greater portion of them consist, however, of brown ferruginous sandstones without any especial characteristic, and it is, as a rule, only towards the base that beds of peculiar character occur. In this position the porous, coarse-grained, friable sandstones, so characteristic of the lowest portion of the group in the Wardha field, usually occur, and it is, as a rule, easy to define the lower limit of the Kámthis and to separate them from the underlying groups; but their upper margin is far less easily determined with accuracy. The compact red and buff shales, and the typical grits breaking with a conchoidal fracture are less common south of the Wardha than to the northward. South of the Godávari,

[1] See Rec. G. S. I., IV, pp. 49, 108.

[2] The estimate of 17,000 feet, mentioned in the Rec. G. S. I., X, p. 28, has since been found to be excessive, and due, apparently, to repetition by faulting.

in the neighbourhood of the Manair (Maner) river, and south of Maḍápúr near Sironcha, there is a great series of sandstones, mostly fine-grained, soft, yellow, salmon-red and reddish-brown in colour, and amongst them is a fine-grained salmon-red sandstone with fragments of purple Vindhyan shale. These beds appear to underlie the massive Kámthi sandstone, and are by Mr. King called the Tárcherla sandstones, from the name of a village on the Manair river. It is, however, by no means clear that the Tárcherla sandstones are really inferior in position to the Kámthis.

The upper Gondwánas occupy all the north-eastern side of the field from the Wardha to below the second barrier on the Godávari, a distance of nearly 100 miles, and between the Wardha and the Godávari near Chinúr these beds occupy a much larger tract than the lower Gondwánas, the upper Gondwána outcrop near Maleri, north-west of Sironcha, being 25 miles across. Owing to the difficulty already noticed, of distinguishing between the upper Gondwána beds and the Kámthis, the limit of the two series is still somewhat doubtful, and this is even more the case south of the junction between the Pránhita and Godávari than to the northward. It remains to be seen how far the upper Gondwánas can be traced to the south-east; they have hitherto not been recognised in the neighbourhood of Dúmagúdem.

In the extreme north-west of the present area, near Jangáon, the upper Gondwána beds completely overlap the lower so as to rest on the underlying Vindhyan rocks, and to occupy the whole breadth of the basin for a short distance. There is nevertheless, as usual, a very close accordance in dip and strike between the upper and lower Gondwána beds, both having in general the same north-east dip, and no marked break can be detected between them.

These beds have not yet been sufficiently thoroughly surveyed to enable their relations to be perfectly understood, but a sub-division into two groups has been indicated by Messrs. King and Hughes, and the former appears disposed to separate a third lower division. The evidence, however, is at present insufficient to prove the distinction, although it is by no means improbable that further sub-division will be necessary.

The Kota-Maleri beds, which have been already described in the general account of the Gondwána system, form the most conspicuous and important group of the series. They occupy the Jangáon valley west-south-west of Sirpúr and a large area on the Wardha, near Sirpúr, and they extend across the country around Maleri (a very small village near the road from Chánda to Sironcha) to the Pránhita, where they are seen at Kota and elsewhere for several miles north of Sironcha.

Hence they extend to the Godávari near Aserali, a few miles above the junction of the Indrávati, and thence along the south-west flank of the quartzite hills on the right bank of the Godávari between the mouth of the Indrávati and Yenchapali (Inchapilly), whilst beds of similar mineral character are exposed in the Godávari about 20 miles further down, below the second barrier which terminates at Yenchapali itself.

The Maleri red clays occupy a large tract in the north-western portion of the Kota-Maleri area, around Jangáon, Bibra, and Maleri. The Kota limestone is rather higher in the series, and has been traced at intervals for 36 miles to the north-west, as far as the neighbourhood of Itial and Bibra, where these beds crop out in a low range of hills, and for about 20 miles to the south-east, the strike being from north-west to south-east, and the dip, like that of the associated beds, to the north-east. In the upper portion of the group, above the limestones of Kota, clays are less developed, and the rocks consist chiefly of sandstone. Besides the main tract of Kota-Maleri beds, there is a detached area on the Godávari west of Chinúr and Sandrápali, apparently brought down by the north-west south-east fault to which the outcrop of Vindhyan quartzites, Tálchirs and Damudas, on the eastern side of the upper Gondwána outcrop, must be attributed.

The suggested separation of the beds at the base of the Kota-Maleri group, on account of some differences in mineral character, and the presence of the two plants belonging to the Rájmahál flora has already been noticed in the sixth chapter of this work. It was shewn that, although the separation of the Sironcha sandstones may be possible, the evidence at present available is quite insufficient to justify the distinction. The separate classification of the uppermost portion of the Gondwána system near Sironcha, under the name of Chikiála group, appears founded on better evidence, although no fossils have hitherto been discovered in the higher beds. The Chikiála beds have been traced for several miles, along the north-eastern boundary of the Gondwána area, in the neighbourhood of Chikiála, north of Sironcha, their extension to the north-west in the direction of the Wardha being probable. To the south-east they have not been traced. Throughout their range they are highly ferruginous, and they furnish the ore used by the iron smelters of the country.

On the southern edge of the Jangáon valley, near the village of Balanpur, and close to the spot where the westernmost extension of the Gondwána beds is covered up by the trap, some soft yellow sandstone occurs, containing carbonaceous markings, and overlying about 5 feet of

shale with thin irregular strings of jet coal, precisely like the Jabalpur coal of the Sátpúra region in character. These beds overlie the Kota-Maleris. Some other beds in the same neighbourhood resemble in character the ferruginous Chikiála sandstone. It is probable that the Balanpur beds belong to a higher group than the Kota-Maleris, and the marked resemblance in the character of the coal tends to suggest that the former may belong to the Jabalpur group, whilst on the other hand there is a possible connection with the Chikiála beds, and consequently the Chikiála and Jabalpur groups may be identical, but the evidence is insufficient to do more than suggest the possibility of this.

Wardha-Pranhita-Godavari basin.—*c. South-eastern extension.*—The south-eastern portion of the Godávari basin forms a well-defined area, only joined to the remaining tract by the narrow neck already mentioned, south-west of Bhadrachelam. The present area comprises the most southerly exposure of lower Gondwána rocks (Damúda and Tálchir) known to occur in India, and their importance, as offering some hope of the discovery of coal within the Madras Presidency, has led to their receiving more attention than similar beds in the region to the north-west.[1]

The tract in question is irregularly shaped. It consists principally of a belt of country running from north-west to south-east for above 50 miles, and in general about 25 miles broad, but expanding towards the south-east into a much broader area, which extends from the Godávari above Rájámahendri for a distance of 60 miles to the south-west, ending within 20 miles of the Krishna (Kistna) river at Bezwáda. This south-eastern portion, however, consisting of upper Gondwána beds alone, belongs to a different section, the outcrops of the eastern coast, and it will consequently be described separately. On the northern portion of the basin, too, there is an expansion to the eastward, forming the coal-field of Madavåram below Bhadrachelam.

The boundaries appear to be for the most part natural. So far as is known, there is no abrupt junction with the older rocks extending for any great distance. Throughout the greater part of the boundary the Gondwána beds rest upon metamorphics; to the south-east, near Ellore, they disappear beneath Deccan trap, tertiary sandstones, and the alluvium of the Godávari and Krishna (Kistna) deltas.

The formations met with in the north-western portion of the area are Tálchirs, Barákars, and Kámthis. The Tálchirs are only seen on the margin of the tract in three localities, in all of which they underlie Barákar beds.

[1] For fuller description, see Rec. G. S. I., IV, pp. 49, 59, 82, 107; V, pp. 23, 112; VI, p. 57; X, pp. 55, &c. Some details are also taken from MS. reports by Mr. King, who is the author of several of the printed papers quoted.

The first of these is on the border of the Madavåram coal-field, east of Bhadrachelam. Here Tálchirs are seen to occur at or outside the northern boundary in three patches, none of which are of any extent, and the largest exposure, which is about 1½ miles long, is nearly, if not entirely, surrounded by metamorphics, and outside the general sandstone boundary. The same rocks are also seen south of the Godávari, at the south-east corner of the Madavåram coal-field. The only other spot where the Tálchirs appear within the boundary is about 25 miles south-west by a little south of Bhadrachelam, on the south-west boundary of the Gondwána area, near a hill called Kanigheri. But several Tálchir outliers are met with about Dúmagúdem and Bhadrachelam outside the edge of the Gondwána area; three at least appear in the bed of the Godávari, below Dúmagúdem; two are very small and almost confined to the bed of the river; but the third, which occurs about 6 miles below Dúmagúdem, extends for 5 or 6 miles to the eastward from the river. Another is met with on the Kinarswámi stream, 5 miles west-south-west of Bhadrachelam, but it is only about 2½ miles across. The irregularity of the distribution of these patches of Tálchirs, and the absence of the formation, as a rule, at the base of the Barákars, appear to shew that the latter are more unconformable to the former than they usually are elsewhere.

The Barákars are found in three localities. The first of these is the Madaváram coal-field on the Godávari, below Bhadrachelam. This is a tract of somewhat irregular form, 7 miles across from east to west, and 5 miles, where broadest, from north to south; it is traversed throughout by the Godávari from west to east, and the area is about 24 square miles. The rocks are very poorly seen, the ground being much covered by alluvial deposits, but from the few dips observed, it appears probable that some of the boundaries are faulted. The portion of this tract north of the river has been explored by boring, and some coal was found, but the quality was inferior, and the seams thin and much mixed with shale, whilst the beds were found to vary much in thickness and composition within a short distance. The tract south of the river has not been thoroughly examined. The sandstones and shales preserve the usual character.

The second tract of Barákars is the Beddadanol field, which lies about 35 miles south-east of Bhadrachelam, and the same distance north by east of Ellore. The large village of Ashraopettah is 5 miles to the westward. This small field is 5 miles from north to south by about 2 broad, the Barákars being completely overlapped both to the north and to the south by the Kámthis; the former rest on metamorphics to the eastward, no Tálchirs occurring, and to disappear

beneath Kámthis to the west. The Barákar area is about 5½ square miles. The only rocks seen at the surface are coarse felspathic sandstones, grey, white, or buff in colour, with ferruginous concretions. At least 600 feet of Barákar rocks would appear to occur, the dip being usually low, from 2° to 10°; some coal has been discovered by boring, but the quality is inferior.

The third tract lies at the spot near Kanigheri already mentioned, 25 miles south-west by south of Bhadrachelam and 15 miles south of Paluncha; it is 6 miles long from north-west to south-east and 2 miles across. The Barákars rest partly on Tálchirs, partly on metamorphics to the westward; they look as if cut off by a fault to the north-west, whilst to the east they are covered up by Kámthis.

The greater portion of the area under description consists of Kámthi beds. Further examination may shew that some strata now assigned to the Kámthis must be referred to a higher formation, but there can be but little doubt of the relations of those rocks which occupy the surface throughout the greater portion of the tract. They are chiefly coarse felspathic sandstones and grits, generally loose textured, and of various shades of brown, often conglomeratic and frequently traversed by ferruginous bands. But at places white, lilac, and red argillaceous shales occur, and in some instances, chiefly along the south-west boundary, the typical yellow compact shale weathering red is seen. In the interior of the tract the Kámthis form large masses of hills, nearly flat-topped, the beds rolling about with very low dips. It appears probable that there is great unconformity between the Kámthis and Barákars, and the extremely local distribution of the latter may be due to their having been largely denuded before the deposition of the Kámthi beds. At the same time there is a possibility that the Barákars were originally deposited in isolated patches.

The Rájmahál beds extend along the south-eastern margin of the Gondwána area, as already mentioned. They will be described separately in the next section.

7. **Kamaram coal-field.**—These are two small outliers, a few miles outside the south-western boundary of the Pránhita-Godávari sandstone area, and situated nearly 40 miles east by a little north from Warangal in the Hyderabad territory, and about 12 miles east-north-east of Pákhal tank. The name of the coal-fields is derived from a small village lying at the southern extremity of the smaller field and 6 miles to the south-south-east of the larger one.[1]

[1] For description by Mr. King, see Rec. G. S. I., V, p. 50. The village is called Kamawaram on the map, and this is probably the correct name, corrupted into Kamáram by the lower classes of natives.

The whole length of the principal field is about 6 miles and its breadth about a mile; it consists of Tálchir, Barákar, and Kámthi rocks, all dipping at a considerable angle to the south-west, and cut off, nearly in a straight line, by one of the usual abrupt boundaries running from north-west to south-east and parallel to the boundaries of the main Godávari area to the north-east. The Tálchirs extend round the north-eastern edge of the field; along the south-western, for part of the distance at least, the Barákars and Kámthis abut against the old Kadapah rocks, by which the field is surrounded. The Tálchirs are the usual fine olive shales, with boulders in places. The Barákars extend for nearly a mile and a half; their breadth, however, is but slight, as only about 300 feet of them appear to occur. They rest upon the denuded edges of the Tálchirs in places, the unconformity between the two groups being clearly shewn. They consist of grey argillaceous sandstone, with beds of coal, two of the coal-seams being of fair quality, and measuring, the one 9 feet, the other 6 feet, in thickness. The small area of the field and the high dip, as well as the distance from road or water carriage, are serious drawbacks. The Kámthis are poorly developed, being about 1,000 feet thick, but occupy only a very small area. They reappear in the smaller outlier at the village of Kamáram. This small basin is only a mile and a half long by half a mile broad, and is of no importance.

8. **Singareni coal-field.**—This is a small outlier,[1] about 30 miles south-west of the main field in the Godávari valley, and 25 miles north by a little east of Khamamet (Kamamet or Kummummett). The present field derives its name from the large village of Singareni, lying about 4 miles west of the southern portion. It is situated in the Kandikonda talúk of the Khamamet Sircar belonging to Hyderabad, and is within the drainage area of the Krishna (Kistna) river.

The Singareni coal-field is irregular in form, extending for about 12 miles from north-north-west to south-south-east, and from one to a little over 2 miles broad. The area is about 19 square miles. The groups exposed are Tálchirs, Barákars, and Kámthis.

The Tálchirs occupy the northern portion of the field only, and consist of the usual fine olive shales, boulders not being common, though some are found. The Barákars are distinctly unconformable to the Tálchirs, and the irregular distribution of the Kámthis and Barákars appears probably also due to unconformity, the former overlapping the latter, and resting sometimes on the Tálchirs, and elsewhere on the old Kadapah rocks or on gneiss.

[1] For description by Mr. W. King, see Rec. G. S. I., V, p. 65.

The Barákars are found in several detached areas, separated from each other by intervening masses of Kámthis. There are two principal areas, one about the middle of the field, and another along its western edge near the southern extremity. In the former a seam of coal was found at the surface, and additional seams, one of them said to be 21 feet thick, have been detected by boring.

VII.—East Coast region.—The representatives of the Gondwána series, which are scattered along the eastern coast of the Peninsula, differ from all those in the interior of the country, in being either chiefly or entirely composed of the Rájmahál group, which, to judge from the remaining outcrops, may once have extended from Rájmahál to Trichinopoly, if not farther south. A portion of the outcrops appear of rather later date than the others, but the difference is not great. Singularly enough, the characteristic flora of the Rájmahál group has not hitherto been found elsewhere, although a few Rájmahál species are found in the Umia beds of Cutch, the Jabalpur group of Central India, and the Kota-Maleri beds near Sironcha,—all of which are believed to be of later date.

Another peculiarity by which the Gondwána outcrops of the east coast are distinguished from all others in India, except the beds of Cutch, is their association with rocks containing marine jurassic fossils. The present section consequently serves as a natural introduction to the account of the Cutch jurassic formations, which will occupy the next chapter.

The localities at which the Gondwána formations are known to occur along the eastern edge of the Peninsula are the following, beginning at the north :—

1. Rájmahál hills (already described).
2. Athgar basin.
3. Outcrops east of Rájámahendri.
4. Ellore area (part of Godávari-Gondwána basin).
5. Ongole outcrops.
6. Sripermatúr outcrops.
7. Trichinopoly outcrops.

The Rájmahál hills have already been described; the other tracts require but brief notice. It is possible that further examination of the country south of Trichinopoly may shew the existence of other representatives of the Rájmahál group, and others, again, may occur between Rájámahendri and Cuttack.

The association of marine fossils with the Rájmahál group along the east coast appears to indicate that these beds were not deposited, like

the other Gondwána formations, in river valleys, but on, or near, the sea-shore. The plant beds may be deltaic or lagoon deposits, but the presence, in several instances, of *Ammonites*, probably indicates that some of the strata must have been formed in the sea itself. In this case, therefore, we have very valuable evidence as to the old shore line; for the association of plants and pelagic shells shews that then, as now, the eastern margin of the Peninsula was a sea-coast, and one of the boundaries of the land traversed by the rivers of the Gondwána period.

2. Athgar (Atgurh or Atgarh) basin.—This is a tract of sandstone, close to the town of Cuttack, on the western edge of the alluvial plain, which extends to the sea-coast.[1] The rocks are very flat and greatly concealed by laterite, which covers them completely to the eastward, whilst a considerable portion of the area is covered with singularly thick, almost impenetrable, bamboo jungle. The name is derived from a zamindári, or estate, in which the portion of the tract first examined is situated.

The area occupied by the sandstones slightly approaches a rectangle in form (the boundaries being, however, very irregular); it is about 20 miles long from north to south, and about 18, where broadest, from east to west. Its boundary to the westward is formed partly by metamorphic rocks, on which the sandstones appear to rest, but chiefly by a plain of alluvium: east and south the sandstones disappear beneath laterite, which a little farther dips also beneath the alluvial plain.

The rocks consist of sandstones, grits, conglomerates containing pebbles of quartzite, &c., white and pink clays, and in one case black carbonaceous shale. This last has only been found at Naráj, on the Máhánadi, west of Cuttack, and may indicate the presence of Barákar beds, but no Damúda fossils have been found associated with it. The relations of the remaining portion of the rocks were obscure until recently, and it was thought that they probably represented the Kámthi (or supposed Mahádeva) beds of the Tálchir coal-field.

Quite lately, however, the following characteristic Rájmahál plants have been found in the Athgar tract[2]: *Alethopteris indica*, *Asplenites macrocarpus*, *Gleichenites bindrabunensis*, and *Palissya indica*; and there can no longer be any doubt but that the Athgar area is one of the

[1] Mem. G. S. I., I, pp. 68, 264; Rec. G. S. I., V, p. 59; X, p. 63. The last-quoted account by Mr. Ball contains a much more complete description of the beds than the earlier notices.

[2] By Mr. Ball. The identifications are by Dr. Feistmantel.

detached patches of upper Gondwána sandstone extending along the eastern coast of the Peninsula.

The sandstones, &c., have a very low dip from west to east, or rather to the south-east, and the beds to the westward appear to be the lowest. These are chiefly composed of coarse conglomerate, which forms low scarps facing the westward. The actual base is nowhere seen. The carbonaceous shale of Naráj appears to owe its appearance at the surface to the elevation caused by a basaltic dyke, which traverses the beds, and is the only known case of their being affected by volcanic action. The age of this basalt dyke is unknown; it is far distant from any known outburst of either Rájmahál or Deccan age, and as no trap dykes occur in the Tálchir country, it is not probable that Orissa is within the area affected by the latter series of volcanic eruptions.

3. Outcrops east of Rajamahendri.—The east coast from Ganjám to Vizagapatam has not been surveyed, but south-east of Vizagapatam, and between that town and Rájámahendri, several outcrops of Gondwána beds have been found.[1] These exposures are six in number, and all are very small, none exceeding 5 miles in length: all are on the edge of the alluvium.

The most eastwardly exposure is close to the coast, about 40 miles north-east of Coconada, where a narrow strip of coarse brown sandstone, about 2 miles long, is seen resting upon the edge of the gneiss hills of Sudi Konda. The next is a similar, but rather larger, outcrop, 8 miles to the south-west, near the village of Eedatum, where the bottom beds are hard, coarse, gritty sandstone, brown in colour, and often containing small pebbles. Half a mile to the south-west, near the village of Jilladypad, is a small ridge, 1½ miles long, surrounded by alluvium, and composed of brown sandy clay and sandstone. Four miles west by south of this again, at Innaparaz-polliam (or Innaparaz-Cotapilly), there is another low ridge, a couple of miles in length, similarly rising from the alluvium, with gneiss ridges to the north. This southern ridge consists of purple and brown sandstones, and conglomerates containing casts of marine fossils, amongst which *Trigonia ventricosa*[2] and *Trigonia smeei*, two of the most characteristic forms of the Umia beds of Cutch, have been recognised. Twelve miles east of this, again, similar beds crop out on the edge of the alluvium near Kirlumpudi, and occupy a rather larger area, extending nearly 3 miles from north to south by 2 miles broad,

[1] The details of these are from manuscript reports by Mr. King. The beds are briefly noticed: Rec. G. S. I., VII, p. 159.

[2] A woodcut of this species will be given in the next chapter. *T. smeei* is figured Pl. XII, fig. 11.

and 8 miles further east at Jagampet there is a sixth outcrop, more than 4 miles in length.

The only one of these outliers which has yielded fossils is that of Innaparaz. From the isolation of these patches, their relations to the Rájmahál beds near Ellore are difficult to trace, but they appear to represent the highest sub-division or Tripetty sandstones.

4. **Ellore**.—On the left bank of the Godávari, near Thalapúdi, about 10 miles above Rájámahendri and 25 miles west of the Jagampet outlier just mentioned, a well-marked belt of upper Gondwána beds commences, which extend from the Godávari to beyond Golapilli, west of Ellore, a distance of 60 miles. The width of this belt varies from 10 to 15 miles. There is a general dip to south-east or east-south-east at 5° to 10°, and the beds rest unconformably, throughout a considerable portion of their area, upon various members of the Kámthi group, but they overlap this group both to the east and west, and rest upon a sloping floor of gneiss, which has the appearance of a plane of marine denudation, formed after the deposition of the Kámthi rocks, as the latter rest upon a much more uneven surface of the metamorphic formations. This appearance of resting upon a surface which had been fashioned by denudation after the deposition of the lower Gondwána beds, quite agrees with the peculiar distribution of the Rájmahál group and its associates, which evidently were accumulated in a distinct area from that in which the Gondwána beds of the Godávari valley were deposited. To the south-east the upper Gondwána beds of the Ellore area disappear beneath the tertiary Cuddalore sandstones and the alluvial deposits of the Godávari delta, except west of Rájámahendri, where the Gondwánas are covered by outliers of the Deccan traps.

The rocks of the Ellore area[1] are peculiarly interesting, because they appear to contain representatives of groups higher than the Rájmahâls, associated with beds in which the typical Rájmahál flora is well preserved. Mr. King, who has surveyed the rocks of the Godávari district, classes the upper Gondwána beds in three sub-divisions, thus distinguished in descending order, as already noticed in the sixth chapter:—

1. Tripetty sandstones.
2. Ragavapuram shales.
3. Golapilli sandstones.

The Golapilli sandstones consist of brown and red sandstones and conglomerates, which, near Golapilli, form a hard plateau capped by conglomerates and gravels, probably belonging to the tertiary Cuddalore

[1] For a description of these beds by Mr. King, see Rec. G. S. I., X, p. 56.

sandstones. In this plateau, near the village of Ravacherla, Mr. King found numerous plant fossils, including *Ptilophyllum acutifolium*, species of *Pterophyllum, Cycadites, Dictyozamites, Palissya, Alethopteris, Asplenites, Gleichenites*, &c., nearly all of which are found also in the Rájmahál group. These fossils occur in a fine yellowish-brown sandstone.

The Golapilli beds extend throughout the area from east of Golapilli to the neighbourhood of the Godávari.

Above the Golapilli beds, about the middle of the area, occur the Ragavapuram shales, with *Ammonites, Leda*, plants, &c., already noticed in the sixth chapter. These shales are traced for about 18 miles, intervening between the Golapilli sandstones and the Tripetty beds. The uppermost group, considered by Mr. King to represent the sandstones of the Innaparaz outlier with *Trigonia ventricosa* and *T. smeei*, extends across the whole tract from Golapilli to the Godávari.

5. **Ongole.**—The outcrops which have been found near Ongole are very numerous,[1] but owing to the manner in which the surface of the country near the coast is covered with laterite, lateritic gravel, and black soil, the rocks are ill exposed, and in many places can only be detected in well sections or excavations for tanks. The most northern exposure hitherto found in the country south of the Krishna river is close to the town of Guntoor; thence to Ongole there is a series of small tracts (five in all) along the edge of the coast alluvium. In these tracts shales and sandstone, very similar to those of Sripermatúr, are exposed. At the town of Guntoor, in well sections, grits and conglomerates are seen, resembling in lithological characters some of the Sripermatúr beds. About 6 miles to the south-east of the town, a long low ridge rises from the alluvium and extends about 14 miles from north-east to south-west, though only about 2 miles broad. This ridge consists of compact brown, reddish and purplish gritty sandstones, probably representing the Tripetty sandstones, and resting upon soft white shales, with ferruginous partings, doubtless identical with the beds of Sripermatúr and Ragavapuram.

The two most important outcrops south-west of Guntoor are those at Inkolu (Yinkolu), 26 miles north by east of Ongole, and at Vamevaram (Wamayavaram), 14 miles north by east of Ongole. In each case, the beds have been traced over 12 to 15 square miles of country. In the Inkolu outcrop, at the village of Budhavada (Boodhawadah), 3½ miles west by north of Inkolu, limestones and calcareous sandstones were found containing large numbers of oysters, besides *Ammonites, Patella, Pecten, Leda, Terebratula, Rhynconella*, and numerous other genera of mollusca.

[1] They have been described by their discoverers, Messrs. C. Æ. Oldham and Foote, in manuscript reports only. See also *ante*, p. 141; and Rec. G. S. I., II, p. 37.

The marine beds apparently are at a lower horizon than the sandy shales seen east of the village from which *Ptilophyllum*, *Dictyozamites*, and other plants were obtained. The plant beds contain a flora, apparently corresponding with that of the Ragavapuram shales, and comprising some species belonging to a higher horizon than the beds of Rájmahál itself and of Golapilli. The fossiliferous marine beds underlying the shales are the upper bands of a group of gritty sandstones, corresponding in position to the Golapilli beds, whilst above the supposed representatives of the Ragavapuram shales there is a hard sandstone, which forms a small plateau north-east of Budhavada, and which may very possibly represent the Tripetty group.

Near Vamevaram a much greater thickness of beds is exposed, consisting of shales, white, buff, and purplish in colour, with flaggy beds and thin bands of sandstone. In some of the higher bands an ammonite (perhaps identical with that met with at Ragavapuram in the Ellore area), a *Leda* (the Ragavapuram species), and impressions of other shells have been found.

Another outlier is found at Yendloor, 6 miles west by north of Ongole, and in some clays and sandy shales a few plant remains were discovered, one of which was a *Ptilophyllum*. Some indurated sandstone occurs at this spot, the relation of which to the shales is obscure.

South of Ongole several other small outcrops have been detected; the principal being west of the town of Kandakur (Cundacoor), 20 miles south-south-west of Ongole, and some highly fossiliferous shales are exposed in well sections at Kandakur itself. It is evident that the representatives of the upper Rájmahál beds here occupy a considerable area beneath the surface covering of laterite. These beds contain many of the usual Rájmahál plants. The most southern exposure of the rocks in this neighbourhood is about 15 miles south of Kandakur, and west of Ramapatnam.

6. **Sripermatur outcrops.**—These are a series of outcrops and outliers, the former along the edge of the metamorphic rocks and intervening between them and the laterite or alluvium of the coast, the latter scattered over the surface of the gneissic rocks. All consist of the Rájmahál group, and apparently of an upper sub-division of the formation, as near Ongole; they commence north-west of Madras and extend to the south-east, considerably beyond the Palar river.[1] None are known to exist more than about 50 miles from the coast.

By far the largest expanse of upper Gondwána beds in this neighbourhood lies west and north-west of Madras, in the neighbourhood

[1] For a complete description by Mr. Foote, see Mem. G. S. I., X, pp. 63-124.

of Sattavedu, Alikúr, and Pyanúr. The southern extremity of this tract is traversed by the Madras railway at a distance of 37 or 38 miles from Madras, a little east of Arconum junction, and the outcrop extends about 35 miles from north to south, being only interrupted for short distances by the alluvium of the Narnaveram and Naggery rivers, which divide it into three subequal divisions near Sattavedu, Alikúr, and Pyanúr respectively. The width of each of these areas is from 5 to 6 miles; in all of them the sandstones of the Gondwána series rest on the metamorphics (the underlying formation in one instance only consisting of Kadapa rocks) to the westward, and disappear to the east beneath laterite and alluvium; large outliers of the laterite being scattered over the sandstones of the Gondwána formations.

The northern portion of this tract, considering it as a whole, consists of the Sattavedu group, consisting chiefly of coarse compact conglomerate. This forms the whole of the Sattavedu area north of the Narnaveram river, and the greater portion of the central or Alikúr area. The southern portion of the latter, and the whole of the tract near Pyanúr, south of the Naggery river, consists of shales, sandstones, uncompacted conglomerate, and boulder beds belonging to the lower or Sripermatúr group. The boulder bed is always found at the base.

The next outcrop is that of Sripermatúr. It lies south-east of the last, being separated from the Pyanúr area by the alluvium of the Corteliar river and an expanse of laterite. The village of Sripermatúr at the northern extremity lies 25 miles west-south-west of Madras. From the neighbourhood of the village the Rájmahál beds are seen for about 15 miles to the southward, and their exposure extends about 9 miles from east to west at the northern end, but the breadth diminishes to the southward. The Rájmahál area is surrounded by laterite, but metamorphic rocks appear here and there through the superficial covering, whilst inliers of the Rájmahál beds are also found, shewing that they exist in places beneath the laterite. The base of the sandstones is nowhere seen.

The whole of this Sripermatúr tract is composed of the Sripermatúr group, and to the northward shales prevail, resting upon gritty sandstone, but in the southern portion of the area coarser beds are found. Remains of plants of Rájmahál species, together with a few higher forms, are common, and near Sripermatúr they are associated with marine shells, as already mentioned in the preliminary description of the group.

The outliers of these rocks to the south and south-west are numerous, but of small size. One group of nearly 30 small outliers, none of them exceeding 2 miles in length, whilst the majority are far smaller, is

scattered over the country south-west of Conjeveram. Another group of rather larger patches extends nearly in a line north and south, to the west of the main road from Madras to Trichinopoly, one outcrop, the southernmost and largest, which is about 4 miles long, being traversed by the road. All consist of Sripermatúr beds.

7. Trichinopoly or Utatur.—The outcrops of the Rájmahál group near Trichinopoly[1] occur in several isolated spots along the western edge of the cretaceous tract north of that town. They all rest upon metamorphic rocks to the westward, and dip to the east beneath the marine cretaceous beds, which rest upon them sometimes conformably, but generally with considerable unconformity, the plant beds having been extensively denuded before the deposition of the cretaceous rocks.

The series of Rájmahál outcrops comprises five distinct exposures, the most northern lying east of Perambalúr, whilst the southernmost is close to the village of Utatúr. The whole distance from north to south over which they are distributed is about 14 miles. The three southern outcrops are close together, and form a nearly continuous fringe to the cretaceous beds for between 6 and 7 miles.

The Rájmahál beds near Trichinopoly consist chiefly of soft sandy clays and micaceous shales, grey and brown in colour, with, at the base, coarse ferruginous sand, containing pebbles and large blocks of gneiss derived from the immediate neighbourhood. This bed is occasionally absent. The gneiss upon which these rocks rest is always greatly decomposed. Plant remains, principally *Ptilophyllum acutifolium,* occur here and there, but the impressions are rarely well preserved. The flora, like that of Sripermatúr and Ongole, appears to indicate a rather higher horizon than that of the typical Rájmahál beds.

[1] For account by Mr. H. F. Blanford, see Mem. G. S. I., IV, pp. 39–49.

CHAPTER XI.

PENINSULAR AREA.

MARINE JURASSIC ROCKS.

Distribution of marine jurassic rocks in India — Area occupied by jurassic beds in Cutch — Relations of Cutch jurassics to higher formations — Physical geology — Sub-divisions — Thickness — Pachham group (Bath) — Chari group (Kelloway and Oxford) — Katrol group (Upper Oxford and Kimmeridge) — Umia group (Tithonian and Portland) — Table shewing distribution of Cephalopoda — Jurassic beds in the great desert north of Cutch — Bálmir sandstones — Jesalmir limestones — Ammonite bed of Kuchri.

Distribution of marine jurassic rocks in India.[1]—In the last chapter the occurrence of marine formations belonging to the jurassic series, but associated with some of the higher Gondwána groups on the east coast of India, has already been noticed. It has been shewn that near Ellore and Ongole, and at Sripermatúr, near Madras, *Ammonites* and other *Mollusca,* with jurassic affinities, have been found in considerable numbers, but that, owing chiefly to the manner in which they are preserved, very few of the species have hitherto been determined, and

[1] The following jurassic fossils are figured on Plate XII :—

Fig. 1. *Belemnites gerardi.*
„ 2. *B. grantianus v. kuntkotensis. B. grantianus v. Kuntkotensis.*
„ 3. *Ammonites (Phylloceras) disputabilis.*
„ 4. *A. (Aspidoceras) perarmatus.*
„ 5. *A. (Stephanoceras) macrocephalus.*
„ 6. *A. (Perisphinctes) pottingeri.*
„ 7. *Goniomya v-scripta.*
„ 8. *Pholadomya granosa.*
„ 9. *P. angulata.*
„ 10. *Trigonia clavellata.*
„ 11. *T. smeei.*
„ 12 *T. costata.*
„ 13. *Astarte major.*
„ 14. *Arca (Macrodon) egertoniana.*
„ 15. *Aucella leguminosa.*

The last two are Himalayan fossils. *Goniomya v-scripta* and *Trigonia clavellata* have not been found in India, but they are characteristically jurassic forms, and allied species occur.

consequently the position of the beds in the jurassic series is, with one exception, still somewhat doubtful; the exception is near Ellore, where two different groups of marine beds have been distinguished, the higher of which corresponds to the Umia group of Cutch.

No other occurrence of jurassic rocks has hitherto been detected in the Peninsula of India itself, but to the north-west in Cutch, in what may be considered an intermediate belt of land between the Indian Peninsula and the remainder of Asia, in a country with the sea on one side and surrounded by alluvial deposits, connected indirectly with those of the great Indo-Gangetic plain, on all others, there is a very important series of jurassic formations, in which several European groups are admirably represented. Besides the area occupied in Cutch itself, the jurassic beds are found in places throughout a considerable area in the great desert to the northward, the best known outcrop being close to the town of Jesalmir.

Area occupied by jurassic rocks in Cutch.—The jurassic area of Cutch [1] may be considered as occupying a number of post-tertiary islands, now connected by alluvial flats. Of these islands the largest is that forming the western and central portion of Cutch, and is about 120 miles long from east to west and about 40 broad. To the north-east of it is the district of Wágad (Wagur or Wagir), another ancient island, nearly 50 miles from east to west, and, excluding alluvium and "Ran," 25 miles broad. Farther north, again, are four isolated masses of hills, chiefly composed of lower jurassic rocks, and extending in a line nearly 100 miles in length from east to west. These are the so-called islands in the Ran;[2] Pachham (Putchum), Kharir (Khurreer or Kurreer), Bela and Chorar; the first, which is farthest to the east, being the largest, and comprising a rock area measuring about 15 miles from east to west and 13 from north to south, whilst in Kharir the rock area measures 19 miles by 10, on Bela 22 by 6, and on Chorar 13 by 4; a few

[1] The rocks of Cutch were first described by Captain Grant, Geol. Trans., Ser. 2, V, p. 289.

The account of this province is taken partly from a report by Mr. Wynne, Mem. G. S. I., XI, pp. 1-293; partly from manuscript notes by the late Dr. Stoliczka. The *Cephalopoda* have been determined by Dr. Waagen, and described in the Palæontologia Indica, Ser. IX. It should, perhaps, be noticed that Dr. Waagen's views of specific distinction differ from those of many palæontologists, and that, as he points out, several of the forms described by him as species might by other naturalists not be considered to rank higher than varieties.

[2] The "Ran" of Cutch is an immense tract, surrounding the province on all sides, except the south, and consisting of barren salt marsh, periodically overflowed by sea water, This tract, which is evidently an ancient sea-basin, now filled up by alluvial deposits, will be further described in a subsequent chapter on post-tertiary and recent deposits.

smaller islands also occur, but none of them are of sufficient size to be worth notice.

Relations of Cutch jurassics to higher formations.—None of the rocks found in Cutch and the adjoining islands are of older date than jurassic. In one spot some limestones containing upper neocomian *Cephalopoda* are found resting upon the jurassic series, the uppermost group of which may perhaps itself be of intermediate age, and belong in part to a lower neocomian horizon.[1] In general the upper jurassic beds disappear to the south beneath the Deccan traps, but marine tertiary beds (nummulitic) overlap the traps and rest upon the older series in many parts of the country, both traps and nummulitic beds being quite unconformable to the jurassic formations.

Physical Geology.—The lowest beds are seen dipping to the south in the Ran islands, Pachham, Kharir, &c., and are again exposed in places in an anticlinal which runs along the northern edge of the province itself near the border of the Ran, the intervening synclinal being, for the most part, concealed beneath the Ran. From the anticlinal near the Ran there is a general dip, varying in amount, to the southward. The greater portion of the series is, however, repeated twice in consequence of a great fault, which runs from east to west along the northern scarp of the Chárwar range of hills south of Bhúj (Bhooj).

Sub-divisions.—By the earlier observers, including Mr. Wynne, the jurassic series in Cutch was simply divided into a lower and an upper group, the former chiefly marine, the latter apparently, for the most part, fresh water, though, as was shewn clearly by Mr. Wynne, no marked line of division can be drawn, for not only is there an absence either of unconformity or of any marked break in lithological character between the two sub-divisions, but marine beds are occasionally found interstratified with the upper, and plant beds with the lower group. The examination of the *Cephalopoda* by Dr. Waagen indicated the probability that representatives of several European jurassic groups existed in Cutch, and Dr. Stoliczka, re-examining the beds with the aid of Mr. Wynne's geological map and his own knowledge of palæontology, found no difficulty in distinguishing four sub-divisions, the three lower of which had been included in the inferior or marine group of previous observers, whilst the upper comprised the higher fresh-water beds, with the uppermost marine strata. The following are the names of the groups

[1] Dr. Stoliczka unfortunately did not live to publish the results of his examination of Cutch, but from his rough field notes it appears probable that the upper neocomian bed of Utra is conformable to the underlying Umia beds. He does not precisely state, however, what are the relations of the upper bed to the lower at this spot.

proposed by Dr. Stoliczka, with their homotaxial equivalents amongst European formations[1] :—

CUTCH.		EUROPE.	
GROUPS.	BEDS.	ZONES.	GROUPS.
	1. Beds with *Crioceras* and *Ammonites* of the *rotomagensis* group.		CRETACEOUS. *Upper Neocomian.*
UMIA	2. Sandstones and shales with *Cycadeæ* and other plants.	?	? WEALDEN.
	3. Sandstones and conglomerates with marine fossils, *Ammonites* (*Perisphinctes*) *eudichotomus, frequens, Trigonia smeei, T. ventricosa,* &c.	Upper Tithonian . Lower Tithonian .	UPPER JURASSIC. *Tithonian and Portland.*
KATROL	4. Sandstones and shales with *Am.* (*Phylloceras*) *ptychoicus, A.* (*Oppelia*), *trachynotus, A.*(*Perisphinctes*) *torquatus, pottingeri,* &c.	Zone of *A.* (*Perisph.*) *mutabilis.* Zone of *A.* (*Oppelia*) *tenuilobatus.*	UPPER JURASSIC. *Kimmeridge.*
	5. Red ferruginous and yellow sandstones (Kantkot sandstones) with *Am.* (*Stephanoceras*) *maya, A.* (*Aspidoceras*) *perarmatus, A.* (*Perisphinctes*) *virguloides, leiocymon.*	? Zone of *A.* (*Pelt.*) *bimammatus.* ? Zone of *A.* (*Pelt*) *transversarius.*	MIDDLE JURASSIC (middle oolite). *Oxford.*
CHARI	6. Oolites (Dhosa oolite) with *Am.* (*Stephanoceras*) *polyphemus, A.* (*Perisphinctes*) *indo-germanus, A.* (*Aspid*) *perarmatus, babeanus, A.* (*Pelt.*) *arduennensis,* &c.	Zone of *A.* (*Amaltheus*) *cordatus.* Zone of *A.*(*Amaltheus*) *lamberti.*	
	7. White limestones with *Am.* (*Pelt.*) *athleta, A.* (*Oppelia*) *bicostatus,* &c.	Zone of *A.* (*Pelt.*) *athleta.*	MIDDLE JURASSIC (middle oolite). *Kelloway.*
	8. Shales with ferruginous nodules with *Am.* (*Perisph.*) *obtusicosta, anceps, A.* (*Harpoceras*) *lunula punctatus,* &c.	Zone of *A.* (*Perisph.*) *anceps.*	
	9. Shales with calcareous bands and locally with golden oolite : *Am.* (*Steph.*) *macrocephalus, tumidus, bullatus, A.* (*Oppelia*) *subcostarius, A.* (*Perisph.*) *funatus,* &c.	Zone of *A.* (*Steph.*) *macrocephalus.*	
PACHHAM.	10. Light grey limestones and marls with *Am.* (*Oppelia*) *serriger,* Corals and *Brachiopoda, &c.*		MIDDLE JURASSIC (lower oolite). *Bath.*
	11. Yellow sandstones and limestones with *Trigoniæ, Corbulæ, Cuculleæ,* &c.		

[1] Waagen; Pal. Ind., Ser. IX: Introduction.

Thickness.—The whole thickness of the Cutch jurassic series has been estimated by Mr. Wynne at 6,300 feet, of which 3,000, or very nearly half, belong to the uppermost group alone; the thickness of the other groups has not been estimated separately. It must be remembered that the base of the whole series is not exposed, and that the upper beds had suffered from denudation before they were covered by the traps.

Pachham group (Bath).—The Pachham group is thus named from its occurrence in the "island" of Pachham in the Ran. The lowest beds are exposed on the northern scarp of a range of hills, which runs east and west through all the Ran islands from Pachham to Chorar. The rocks composing the range dip south at a low angle; the crest of the hills and the surface of their southern slopes are formed of a thick massive bed of yellowish sandstone and limestone, containing *Corbula pectinata, Astarte compressa,* a *Trigonia* closely resembling *T. interlævigata, Cucullæa virgata* and other fossils.[1] Below the massive bed come shales and sandstones, all more or less calcareous, containing a *Rhynconella* near *R. concinna, Lima, Gervillia,* a small *Exogyra,* &c. The lowest bed seen in Pachham island is calcareous sandstone abounding in the small *Exogyra.* The same lower beds are seen in Koari Bet, a small islet north-west of Pachham, and on the northern flank of the range in Kharir, Bela, and Chorar, the top of the range in all cases consisting of the yellow calcareous rock. The thickness of this portion of the beds is at least 500 feet.

Besides forming the range of hills in the islands of the Ran, the Pachham limestone is exposed at four places in Cutch itself,—at Jarra, Kira hill near Chári, Jura hill, and in Halamán hill near Lodai, all situated along the northern edge of the main province of Cutch, near the borders of the Ran. In all these places the Bath rocks appear as inliers, exposed at the crest of an anticlinal, and surrounded on all sides by higher beds. At Jarra, about 50 miles north-west of Bhúj, there is a bed of white limestone containing *Scyphia,* a *Terebratula,* and small *Rhynconellæ,* and immediately above it a bed of corals. These rocks do not appear to be equally well exposed elsewhere; they are at the base of the Chári group, and are considered by Dr. Stoliczka as the uppermost beds of the Pachham group of Cutch.

The lower portion of the Pachham group has yielded no *Cephalopoda,* and the higher beds only eight species, all of which are rare. One is a *Nautilus, N. jumarensis;* the others are *Ammonites,* of which one belongs to

[1] As only the *Cephalopoda* of the Cutch beds have been properly compared, it is possible that some of the identifications of other fossils may require modification. Only those are mentioned which are in all probability correctly determined.

the sub-genus *Oppelia,* three to *Stephanoceras,* and three to *Perisphinctes.* One *Stephanoceras* is a variety of *Ammonites macrocephalus* (Pl. XII, figs. 3, 3*a*) the typical form of which is abundant in the next higher sub-division, and both the other species of *Stephanoceras* pass likewise into the lower beds of the Chári group. With the exception of *A. macrocephalus,* the only species found also in European rocks is *A.* (*Oppelia*) *serriger,* which was originally described from upper Bathonian beds. So far as the *Cephalopoda* are concerned, it would be difficult to correlate the Pachham group with any sub-division of the European oolites, but the Pachham *Brachiopoda,* which, however, have not been thoroughly compared, and the position of the beds immediately beneath the strata containing *A. macrocephalus* in abundance, have induced Drs. Stoliczka and Waagen to refer the group to the horizon of the Bath oolite (Bathonian).

Chari group (Kelloway and Oxford).—The next group in ascending order derives its name from the village of Chári, situated in Northern Cutch, about 32 miles north-west of Bhúj (Bhooj) and close to the borders of the Ran. This village has been known since the time of Captain Grant, the earliest geological explorer of Cutch, as an admirable locality for fossils, and especially for *Cephalopoda,* of which large numbers are found in the calcareous sandstones exposed around Kira hill.

The Chári group is composed of four sub-divisions, each marked by its mineral characters and by the fossils it contains. The group, as a whole, is in Cutch much more shaly than any of the other sub-divisions, but it contains hard bands of limestone or calcareous sandstone forming ridges, which are usually distinguished by characteristic forms of *Ammonites.*

The lowest of the four zones or sub-groups consists of shales, usually of a grey colour, with occasional bands of golden oolite, and sometimes nodular shaly limestone. The rock called golden oolite (which is not peculiar to India, but which is also found in the jurassics of Europe, and at about the same horizon) is very characteristic and easily recognised. It is a rather coarse-grained limestone, composed of calcareous grains, which are coated with a very thin ferruginous layer, and are surrounded by a matrix of carbonate of lime, so that the stone has much the appearance at first sight of a rock with golden-coloured mica. In places, as at Chári itself, the golden oolite is thick and conspicuous, but it is locally distributed and often wanting. The most characteristic fossils of these lowest Chári beds are *Ammonites* (*Stephanoceras*) *macrocephalus,* and allied forms of the sub-genus *Stephanoceras.*

Above the *macrocephalus* beds come dark shales, often black, with ferruginous bands and concretions. Sometimes, however, the nodules

are of white limestone, and the shales are locally sandy, and associated with sandstones, but the beds appear to preserve their lithological characters in general throughout Cutch. The chief palæontological peculiarity of this sub-division is the extreme abundance of a *Terebratula* considered by Sowerby a variety of the cretaceous *T. biplicata*. Planulate *Ammonites* (*Perisphinctes*) are also very common. The shales not unfrequently contain remains of plants, but no distinct impressions have been found.[1]

The next sub-division, in ascending order, is a very thin band, sometimes only 20 to 30 feet thick, of whitish or grey shale, with bands of limestone, which are generally white, but occasionally yellowish or brown. Usually this band may be recognised easily by its colour and by its presence beneath the Dhosa oolite. The most characteristic fossil is *Ammonites* (*Peltoceras*) *athleta*, and in North-Western Cutch the shell of this mollusk is usually changed into black calcspar.

The uppermost Chári sub-division is both lithologically and palæontologically the most characteristic of all. It is of no great thickness, though more developed than the *athleta* beds, and consists of grey, reddish, or brown oolite, sometimes sandy and often nodular. It abounds in many places in a *Terebratula* closely allied to the cretaceous *T. sella*, and referred to that species as a variety by Sowerby: *Cephalopoda* are also extremely abundant.

The Chári beds are exposed in several places in Cutch, but they nowhere occupy a large area. They are found resting upon Pachham beds in the southern part of Pachham and Kharir islands, and in two small islands, Kakindiya and Gángta, south-east of Kharir (they form only the axis of a quaquaversal anticlinal on the latter); but none are exposed in Bela or Chorar, though a small area exists in the extreme north of Wágad. In these outcrops the sub-divisions are less well marked than to the southward, and the two characteristic *Terebratulæ* have not been noticed. In the mainland of Cutch, the Chári group occupies two series of inliers. One of these series is scattered at intervals along the northern anticlinal range; the rocks appear at three places west-north-west of Chári, again around Kira hill, near Chári, the typical locality; they extend nearly 12 miles from east to west around the Pachham beds of Jura hill, north of Bhúj, and they are found in two more outcrops farther east around Halamán hill, where they extend more than 6 miles,

[1] In Dr. Stoliczka's field notes he mentions having at one locality found fragments of quartz and of a limestone derived from one of the lower groups, probably from the Pachham beds, cemented together in the rock at this horizon. This may indicate unconformity.

and they again appear a mile farther east. Another series of outcrops occurs in the Chárwar range, south of Bhúj. Here the Chári beds are brought up at intervals along the southern side of the great fault; they are greatly disturbed and cut up by cross faults, but the different bands can be easily recognised,—the Dhosa Oolite with *Terebratula sella*, var., the white *athleta* beds, and the band with *T. biplicata*, var., being always conspicuous.

The relations between the *Cephalopoda* found in the different sub-divisions of the Chári group, and the corresponding Kelloway and lower Oxford groups in Europe, are the following, according to Dr. Waagen. The Chári fauna is very rich, comprising altogether 112 species, of which 37 are European. In the lowest Chári sub-division, or *macrocephalus* beds, 31 *Cephalopoda* have been found, *viz.*, 2 species of *Belemnites*, 3 of *Nautilus*, and 26 of *Ammonites*, of which 2, including *A. disputabilis* (Pl. XII, fig. 3), belong to the sub-genus *Phylloceras*, 1 to *Lytoceras*, 1 to *Oppelia*, 1 to *Harpoceras*, no less than 13, including *A. macrocephalus* (Pl. XII, figs. 5, 5*a*), to *Stephanoceras*, and 8 to *Perisphinctes*. Three are common to this sub-division and the upper Pachham beds, whilst none are known to range into higher strata. Sixteen species, or rather more than one-half, are found in Europe, all, except two, belonging exclusively to the beds with *A. macrocephalus* (Lower Kelloway).

In the next sub-division, the dark shales with *Terebratula biplicata*, var., 27 *Cephalopoda* are found, *viz.*, 3 *Belemnites*, 1 *Nautilus*, 1 *Ancyloceras*, and the remainder *Ammonites*, amongst which 2 belong to *Phylloceras*, 3 to *Oppelia*, 5 to *Harpoceras*, 1 to *Stephanoceras*, and 11 to *Perisphinctes*. Six of these range into higher beds, whilst 7 are European, and of these latter 5 are only found in the beds with *A. anceps* (Middle Kelloway).

The *Athleta* beds have yielded 20 species: 3 *Belemnites* and 17 *Ammonites* (*Phylloceras* 1, *Amaltheus* 2, *Oppelia* 2, *Harpoceras* 2, *Peltoceras* 1, *Aspidoceras* 2, and *Perisphinctes* 7); 5 of these are common to the next lower sub-division, and 2 to the Dhosa Oolite. Eight are European, six being peculiar to the zone of *A. athleta* (Upper Kelloway).

In the Dhosa Oolite no less than 34 *Cephalopoda* have been found, *viz.*, 4 *Belemnites*, 1 *Nautilus*, and 29 *Ammonites* (*Phylloceras* 2, *Harpoceras* 1, *Peltoceras* 5, *Aspidoceras* 4, *Stephanoceras* 8, and *Perisphinctes* 9); of these 4 range into higher and 3 into lower beds. Eight are found in Europe (the most important being *Am.* (*Aspidoceras*) *perarmatus* (Pl. XII, figs. 4, 4*a*); and of these seven belong exclusively to the zones of *A.* (*Amaltheus*) *lamberti* and *A.* (*Amalth.*) *cordatus* (Lower Oxford). This group also abounds in other fossils, especially, as already mentioned, in *Terebratula sella*, var.

Katrol group (Upper Oxford and Kimmeridge).—The Katrol group, which rests upon the uppermost sub-division of the Chári beds, is of considerable thickness. It consists of sandstones of various kinds, white, brown, pinkish-grey, &c., and shales usually grey or reddish, but sometimes very dark coloured like those of the *Am. anceps* zone. Ferruginous nodules and concretions sometimes occur in the shales which prevail towards the base of the group, the upper portion being chiefly sandstones. On the whole, however, shales predominate.

These beds form two belts in Cutch proper. The first occurs in the anticlinal along the Ran and extends for nearly 80 miles, surrounding the inliers of the Pachham and Chári groups, and extending to a considerable distance beyond them. The exposure of Katrol rocks varies in breadth, being, where broadest, nearly 10 miles wide. The second belt is in the Chárwar range, south of the great fault; this tract is about 35 miles from east to west, but nowhere more than 2 miles broad. Besides this, beds apparently belonging to the same group occupy the greater part of Wágad. The rocks are very similar in mineral character, consisting of coarse and fine grey, pinkish and white sandstones above, and grey or yellowish shales below; but the *Cephalopoda* found are almost all distinct, and appear to indicate a lower horizon. From their development around the town of Kantkot, these Wágad beds have received the name of Kantkot sandstone.

The *Cephalopoda* of this Kantkot sandstone are nineteen in number, 4 *Belemnites* and 15 *Ammonites* (*Phylloceras* 1, *Aspidoceras* 2, *Stephanoceras* 5, *Perisphinctes* 7). Four of these, *Am.* (*Aspidoceras*) *perarmatus*, *A.* (*Stephanoceras*) *maya*, *fissus*, and *opis*, are also found in the Dhosa Oolite of the Chári beds, whilst only one species, *Belemnites grantianus* (*B. kuntkotensis*, Pl. XII, fig. 2), is common to the Kantkot bed and the Katrol group in Cutch proper. Thus the Kantkot beds appear by their cephalopodous fauna allied more closely to the uppermost Chári beds than to the Kantkot group. Three species only of the Kantkot *Cephalopoda* are European, *A.* (*Asp.*) *perarmatus*, *A.* (*Per.*) *plicatilis*, and *A.* (*Per.*) *martelli*, and only one of these, the last, is limited to a single zone, that of *A.* (*Pelt.*) *transversarius* (Upper Oxford) in Europe, the other two ranging lower. Several forms are, however, allied to upper Oxfordian species.

The Katrol group proper has yielded 26 species of *Cephalopoda*, 4 *Belemnites* and 22 *Ammonites* (*Phylloceras* 2, *Lytoceras* 1, *Haploceras* 2, *Oppelia* 4, besides an *Aptychus*, *Harpoceras* 1, *Aspidoceras* 5, *Perisphinctes* 7). Only one of these species, *Bel. grantianus*, is found with certainty in any other group in Cutch. Four species are found in Europe, all belonging to the beds of the Kimmeridge group, with *A.* (*Asp.*) *acan-*

thicus. Of the above *Cephalopoda*, by far the most characteristic and abundant is a non-canaliculate Belemnite, *B. katrolensis*. The commonest *Ammonites* are *A.* (*Oppelia*) *kachhensis*, *A.* (*Per.*) *pottingeri* (Pl. XII, figs. 6, 6*a*), *A.* (*Per.*) *katrolensis*, and *A.* (*Per.*) *torquatus*.

Imperfect plant remains are common in the Katrol group, as they are in many of the lower beds of Cutch, but in one instance near the village of Narha, as has already been mentioned in the description of the Gondwána series, Mr. Wynne found, in shales interstratified with the Katrol beds, and distinctly inferior in position to some of the marine bands of the group, several remains of plants, of which four species, *Sphenopteris arguta*, *Alethopteris whitbyensis*, *Otozamites contiguus*, or an allied form, and *Araucarites cutchensis*, have been identified by Dr. Feistmantel. The relations of these plants have been already discussed on a previous page.

Umia group (Tithonian and Portland).—The Umia group derives its name from a small village in Western Cutch, rather more than 50 miles north-west of Bhúj. Taken as a whole, this group appears to equal in development all the other jurassic beds together, being, according to Mr. Wynne's estimate, upwards of 3,000 feet thick. It is the equivalent of the upper Jurassic group of Mr. Wynne's Memoir. As a rule, it consists of sandstones of various kinds, and more or less sandy shales. The sandstones are very often soft and white or pale-brownish, sometimes variegated, and very generally distinguished by thin bands of hard black or brown ferruginous grit. Occasionally the sandstones are variegated with pink, red, and brown; they are often very argillaceous and tend to decompose into a loose sandy soil, which covers and conceals the rocks over a great part of the country. In a few instances carbonaceous shale occurs, and in one locality, a thin seam of bright jetty coal. A few thin hard bands of sandstones are met with, some being so hard as to be almost a quartzite. There is a marked resemblance in the beds of this group to some of the upper Gondwána strata of Central India; there are the same soft argillaceous sandstones and sandy shales and the same hard ferruginous gritty bands.

Towards the base of the Umia group, there is a thick band of calcareous conglomerate, hard and grey, sometimes ferruginous, associated with sandstones and shales. In the conglomerate and in some associated beds marine fossils are numerous. Throughout all the rest of the group remains of plants are common, but they are not often sufficiently well preserved to be identified; marine fossils are very rare, but *Trigonia smeei*, the most typical fossil of the group, has been found in places, as near Vigor, 40 miles north-west of Bhúj, in beds near the top of the group and well above the horizon at which most of the plant fossils have been obtained.

The beds of the Umia group are covered unconformably by the Deccan traps and by tertiary rocks, except in one place, where, as already mentioned, they underlie the upper neocomian (Aptien) beds of Ukra hill in North-Western Cutch.

The surface occupied by the rocks of the Umia group corresponds in magnitude with the thickness of the formation, and embraces nearly, if not quite, half of the jurassic area in Cutch. In Cutch proper these beds extend throughout the province from the western extremity near Lakhpat to the eastern end beyond Bachao, forming a great plain south of the irregular range of hills along the edge of the Ran. They also extend round each end of the range, especially to the eastward, where the bottom Umia beds extend about 20 miles along the Ran north of the hills near Juran and Lodai. The main belt of Umia beds is from 8 to 12 miles across on an average; these rocks lap round the western end of the Chárwar range, where the great east and west fault, to which the range is due, appears to die out, and they cover another plain, nearly 50 miles in length from east to west and about 8 miles broad, south of the Chárwar range. They also form the western portion of Wágad.

The plant remains of the Umia group and their relations have already been described in the chapter relating to the Gondwána system. It was there shewn that 23 species had been identified, of which the commonest is *Ptilophyllum cutchense* (Pl. XI, figs. 3, 4), and of which 10 are either common to the lower oolitic beds of Yorkshire or represented by very closely allied forms. Bearing in mind that the plant beds are superior in position to all the portion of the group which has furnished *Cephalopoda*, it is remarkable to find that the latter exhibit a very decided upper oolitic (Portland and Tithonian) facies.

They are eleven in number,[1] *viz.*—

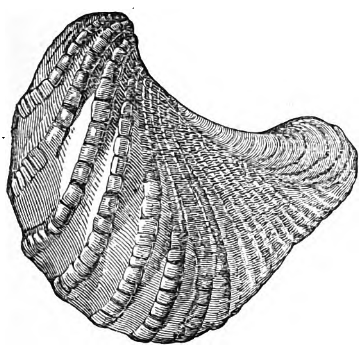
Belemnites grantianus (*kuntkotensis*).	*A.* (*Perisphinctes*) *bleicheri.*
Belemnites, 2 sp. indet.	*A.* (*Per.*) *occultefurcatus.*
Am. (*Haploceras*) cf. *tomephorus.*	*A.* (*Per.*) *eudichotomus.*
A (*Aspidoceras*) *wynnei.*	*A.* (*Per.*) *frequens.*
A. (*Perisphinctes*) cf. *suprajurensis.*	*A.* (*Per.*) *denseplicatus.*

Of these eleven species, one, *Belemnites grantianus* v. *kuntkotensis*, is found in lower beds in Cutch, and the two other forms of *Belemnites* are closely allied to the Katrol species *B. claviger* and *B. katrolensis*,

[1] Nine, according to Dr. Waagen, Pal. Ind. Ser. IX, pp. 225, 232, but he appears to have overlooked two forms—*Belemnites kuntkotensis* (*grantianus*), stated at page 4 to have been found in Umia beds, and the specimens from the same group doubtfully referred to *B. claviger*, p. 7. These very trifling and unimportant oversights are not noticed in order to call attention to a trivial error, but because the relations of the Umia group are of considerable importance and have been disputed. In consequence of the great importance of this group, the evidence upon which its relations to the upper jurassic beds of Europe are based is given in full.

and may be identical. All the eight *Ammonites* are restricted in Cutch to the Umia group, but two of them, *A. tomephorus* and *A. eudichotomus*, are Tithonian species found in the uppermost jurassic beds of Southern Europe, whilst *A. bleicheri* and *A. suprajurensis* are found in the Portland strata of Northern France, and *A. occultefurcatus* is barely distinguishable from another Portland species, *A.* (*Perisphinctes*) *boidini*, Lor. The connexion between the *Cephalopoda* of the Umia group and the forms found in the uppermost jurassic beds of Europe is consequently very marked, despite the small number of species found in the former, and Dr. Waagen states that the same marked similarity exists between the lamellibranchiate bivalves or *Pelecypoda* of the same beds in the two regions.[1]

The *Cephalopoda* are, however, rare and exceptional in the Umia group, and they form by no means so important a portion of the fauna as they do in the Chári, and even in the Katrol group. The commonest Umia fossils are two species of *Trigonia*, *T. smeei* (Pl. XII, fig. 11), and *T. ventricosa*, the latter being also found in the uppermost jurassic rocks of South Africa, whilst a very closely allied form, *T. tuberculifera*, occurs in cretaceous beds in Southern India. The occurrence of both of these *Trigoniæ* in jurassic beds associated with upper Gondwána strata on the east coast of India near Rájámahendri has already been noticed. Other forms of common occurrence in the Umia group are *Trigoniæ* allied to *T. vau*,



Trigonia ventricosa, natural size.

[1] Pal. Ind., IX, p. 225. Dr. Feistmantel, however (Rec. G. S. I., 1876, IX, p. 116), has contended that some of the forms found in the upper Cutch beds shew affinities to middle and lower jurassic forms. This is doubtless the case, and it is equally certain that some Umia fossils are allied to cretaceous forms, but no accurate conclusions as to the relations of a fauna can ever be attained by selecting a few species only for comparison. In the case of *Trigonia ventricosa* and a *Trigonia* related to *T. vau*, quoted by Dr. Feistmantel as proving an affinity to older formations, a mistake has been made in supposing that these fossils belong to beds in Africa of middle or lower jurassic age. This was formerly supposed to be the case (Q. J. G. S., 1867, pp. 169, 171, &c.), but it has since been shewn by Mr. Stow (Q. J. G. S., 1871, pp. 502, &c.) that *T. ventricosa* and *T. vau* are the characteristic fossils of one of the uppermost jurassic zones, resting upon a bed which contains *Hamites*, a cretaceous genus, and a neocomian form of *Crassatella*. The evidence, therefore, afforded by this important fossil, *Trigonia ventricosa*, confirms in a most signal manner the views adopted by Dr. Waagen from a study of the *Cephalopoda*. Some other Umia fossils appear also closely related to species found in the upper jurassics of Southern Africa; for instance, the *Gervillia* appears undistinguishable from the African *G. dentata*

T. clavellata (Pl. XII, fig. 10), and *T. gibbosa, Astarte major* (Pl. XII, fig. 13), a *Gervillia*, a peculiar *Gryphæa*, intermediate in form between *G. dilatata* and *G. vesicularis, Goniomya*, &c. Some of these range into lower groups also. A portion of the jaw of a *Plesiosaurus* was also obtained from these beds, and it has been described as *P. indicus.*[1]

Owing to the circumstance that, with the exception of the *Cephalopoda*, the large collections of fossils made in Cutch by Messrs. Wynne, Fedden, and Stoliczka have not hitherto been examined and compared, the distribution of many of the most characteristic species has not been definitely ascertained. Amongst the forms which are most abundantly preserved in the lower groups of the Cutch jurassic series are species of *Pleurotomaria, Pholadomya granosa* (Pl. XII, fig. 8), *Ph. angulata*, (Pl. XII, fig. 9), *P. inornata, Corbula lyrata, C. pectinata, Nucula cuneiformis, Cucullæa virgata, Trigonia costata* (Pl. XII, fig. 12), and *Ostrea marshii.*

Table shewing distribution of Cephalopoda.—The following table shews the general result of Dr. Waagen's examination of the Jurassic *Cephalopoda* found in Cutch:

Name of group.	Name of sub-division.	Total number of *Cephalopoda*.	Species peculiar to group.	Species ranging into higher beds.	Species ranging into lower beds.	Common to European jurassics.	REMARKS.
UMIA	3. Marine beds	11	9	—	2	4	Two of the European species occur in Portland beds of Northern France and two in Tithonian beds of Southern Europe.
KATROL	4. Katrol beds proper.	27	26	1	1	4	All the four European species belong to the zone of *Am. acanthicus* (Kimmeridge).
	5. Kantkot beds	19	14	1	4	3	
CHARI	6. Dhosa Oolite (*Ter. sella* beds).	34	27	4	3	8	Seven characteristic of the zone of *A. transversarius* (Lower Oxford) of Europe.
	7. *Athleta* beds	20	13	2	5	8	Six characteristic of the zone of *A. athleta* in Europe.
	8. *Anceps* beds with *Ter. biplicata.*	27	21	6	—	7	Of the seven species found also in Europe, five are peculiar to the beds with *A. anceps.*
	9. *Macrocephalus* beds.	31	28	—	3	16	Fourteen out of the sixteen exclusively found in beds with *A. macrocephalus* in Europe.
PACHHAM	Upper	8	5	3	—	1 or 2	
	Lower	—	—	—	—	—	

The correspondence, not only with the European jurassic rocks as a whole, but with the different groups into which they are divided, is remarkable, and greater than is known in any other Indian formations, the

[1] Lydekker: Rec. G. S. I., IX, p. 154; X, p. 41.

only other series of Indian rocks of which the fauna has been sufficiently examined to justify the comparison—the cretaceous series of Southern India—shewing much less close agreement in the distribution of the fauna, and especially of the *Cephalopoda,* with the corresponding groups in Europe. The only remarkable instance in which the *Cephalopoda* of the Cutch jurassics differ from their representatives in the jurassic rocks of Europe, is in the prevalence in the Indian area of the *macrocephali* ammonites (*Stephanoceras*) at a higher horizon than in Europe. In Cutch they abound in the Dhosa Oolite and Kantkot sandstone, the other *Cephalopoda* of which are of Oxford, and in the latter case of upper Oxford types, whilst in Europe they are not known above the base of the Kelloway group. As will, however, be shewn in the next chapter, some of the cretaceous forms of *Ammonites* found in Southern India shew a remarkable resemblance to the jurassic forms of *macrocephali,* and in this instance they are associated with species allied to *Ammonites* characteristic of even older European deposits.

Jurassic beds in the great desert north of Cutch.—The occurrence of jurassic fossils in the wild semi-desert tract lying to the north of the Ran of Cutch has been known for many years. A few species were obtained from the country immediately north of the Ran by Sir H. Pottinger, and these were figured and described,[1] together with the much larger collections made by Captain Grant and Captain Smee in Cutch. Amongst the species thus obtained were *Ammonites pottingeri* and *A. torquatus,* both of which in Cutch have only been found in the Katrol group. The rocks immediately north of the Ran have never been explored by a geologist, but farther north, near Jesalmir, some jurassic *Ammonites* were discovered by Dr. Impey[2] in 1858, and a few data have since been added by a traverse made in 1876.[3] It is probable that a considerable area in the desert is occupied by jurassic strata, but the rocks are concealed throughout the greater portion of the region by a great thickness of sand. The only localities which have hitherto been examined are in the neighbourhood of Jesalmir to the north and Bálmir to the south.

Three beds in particular have been recognised amongst the strata exposed, but only one of these can be referred even approximately to a definite horizon amongst the Cutch series. The beds are in descending order:—

1. Ammonite bed of Kúchri.
2. Jesalmir limestones.
3. Bálmir sandstones.

[1] Geol. Trans., Ser. 2, V, p. 715, Pl. LXI.
[2] Jour. Bom. Br. R. A. S., VI, p. 161.
[3] Rec. G. S. I., X, pp. 10, 21.

Balmir sandstones.—The Bálmir rocks consist of sandstones, grits, and conglomerates, the most characteristic beds being whitish or greyish sandstone, very fine and compact, and a still finer rock approaching a compact shale, white, but veined and blotched with purple. These beds must attain a considerable thickness, but only the lowest are well exposed, the upper strata being probably softer. The lower members of the group are well seen at Bálmir itself, where they rest upon the altered volcanic rocks of Maláni, and in some hills near Náosir, about 30 miles farther east. Fragmentary plant remains are common, but nothing sufficiently well preserved for determination has been found, and no remains of animals have been detected in the beds.

East and south-east of Jesalmir, beneath the marine jurassic beds of the next group, a considerable thickness of white, grey, and brown sandstones is exposed, interstratified with numerous bands of hard black and brown ferruginous sandstone and grit. Towards the base are some soft argillaceous sandstones, streaked and blotched with purple and closely resembling the Bálmir beds, except that they are less hard. These rocks probably belong also to the Bálmir group. They have a great resemblance to the Umia group of Cutch and to some of the Gondwána beds of the Central Provinces. The only fossils found, except fragments of leaves, are some pieces of dicotyledonous fossil wood.

Jesalmir limestones.—The sandstones and limestones of Jesalmir rest upon the beds last described, and consist of thick bands of compact buff and light brown limestone interstratified with grey, brown, and blackish sandstone, with some conglomerate. The limestone forms conspicuous scarps close to the town of Jesalmir, and it is highly fossiliferous, containing amongst other species *Terebratula biplicata, T. intermedia, Pholadomya granosa, Corbula lyrata, C. pectinata, Trigonia costata, Nucula cuneiformis, Pecten lens, and Nautilus kumagunensis. Ammonites* (*Stephanoceras*) *fissus* has been obtained from the neighbourhood, but very possibly from a different horizon, for in Cutch it belongs to the Dhosa Oolite and the Kantkot sandstone (both Oxford), whilst *Nautilus kumagunensis* is only found at a lower horizon in the beds with *Am. macrocephalus* at the base of the Chári group. *Terebratula biplicata* in Cutch is chiefly characteristic of a rather higher horizon than that of the *macrocephalus* beds. There can, however, be but little hesitation in referring the Jesalmir limestones to the age of the Chári group.

Ammonite bed of Kuchri.—The Ammonite bed of Kúchri is exposed about 25 miles west-north-west of Jesalmir, and consists of a thin bed of buff and brownish limestone, weathering red where exposed, and abounding in yellow *Ammonites* of three or four species. None of the *Ammonites* can be safely identified with any Cutch species, though one

form is very near *A.* (*Stephanoceras*) *opis*, which, like *A. fissus*, is common to the Dhosa Oolite and Kantkot sandstone. Below the Ammonite beds are dark calcareous sandstones resting upon soft white sandstone, and similar beds are found above, the whole being capped, a few miles to the westward, by nummulitic limestone. The relations between the Kúchri bed and the Jesalmir limestone are not clearly seen, but the former appears to be higher in the series.

Jurassic rocks, probably belonging to the Umia group, have recently been found by Mr. Fedden to exist in Northern Kattywar. To the north of Jesalmir the rocks may extend into Bikanir. The jurassic rocks of the Panjáb Salt Range and of the Himalayas will be described in a subsequent chapter.[1]

[1] After the first pages of this chapter had been passed for press, it was noticed that an omission of some importance had been made with regard to the Ammonites of the Sripermatúr beds; *ante*, pp. 149, 250. Dr. Waagen, Pal. Ind., Ser. IX, p. 236, pointed out that these *Cephalopoda* resembled Neocomian rather than Jurassic types. As, however, owing to the poor state of preservation, the species cannot be determined, Dr. Waagen has himself noticed (Denkschrift mat. nat. klasse K. Akad. Wiss. Wien., 1878) that too much weight must not be attached to so imperfect an identification.

CHAPTER XII.

PENINSULAR AREA.

MARINE CRETACEOUS ROCKS.

Neocomian beds of Cutch — Middle and upper cretaceous beds of India — Cretaceous rocks of Trichinopoly and Pondicherry — Area occupied — Sub-divisions — Utatúr group — Distribution — Palæontology — Trichinopoly group — Distribution — Palæontology — Arialúr group — Distribution and relations to lower groups — Palæontology — Uppermost Arialúr beds of Ninnyúr — Relations between faunas of different groups — Physical geography of Southern India in cretaceous times — Connexion with cretaceous rocks in other parts of India — Relation to cretaceous rocks of South Africa — Cretaceous fossils of Sripermatúr near Madras — Cretaceous beds of the Narbada valley or Bágh beds — Mineral characters and distribution — Physical geology — Palæontology — Relations to cretaceous fauna of Southern Arabia.

Neocomian beds of Cutch.—Before proceeding to describe the other cretaceous rocks[1] of the Indian Peninsula, all of which are of middle or upper cretaceous age, it may be useful to notice briefly the existence of a band belonging to a lower cretaceous horizon in Cutch.[2] To the occurrence of this band attention has already been directed in the description of the jurassic beds of the same province.

[1] The following cretaceous fossils are figured on Plate XIII:—

Fig. 1. *Ammonites rotomagensis.*
„ 2. *A. planulatus.*
„ 3. *Turrilites costatus.*
„ 4. *Baculites vagina.*
„ 5. *Aporrhais securifera.*
„ 6. *Avellana scrobiculata.*
„ 7. *Cardium (Protocardium) hillanum.*
„ 8. *Trigonia scabra.*
„ 9. *Inoceramus simplex.*
„ 10. *Pecten (Vola) quinquecostatus.*
„ 11. *Hippurites organisans.*
„ 12. *H. cornuvaccinum* (transverse section).

All are Indian fossils, except the *Hippurites*, which have been introduced because of the great abundance of forms belonging to the genus in many cretaceous formations found in parts of Europe and Asia.

[2] The only published account of this bed is in the "Palæontologia Indica," Ser. IX, Jurassic Cephalopoda of Cutch, pp. 245-247. No account of the locality was ever printed by the discoverer, Dr. Stoliczka, and his note-books contain scarcely any details on this particular point.

The only representative of the marine cretaceous formations known to occur in Cutch is a thin bed of ferruginous oolitic rock which occurs at the base of the Deccan traps forming Ukra hill, 7 miles south-east of Lakhpat, in North-Western Cutch, and rests upon beds of the Umia group. The outcrop is very ill seen, and nothing has been definitely ascertained as to the degree of conformity between the cretaceous bed and the underlying formation, but there appears to be no marked contrast between them.

The following three fossil *Cephalopoda* have been obtained from this locality :—

Ammonites martini.
A. deshayesi.
Crioceras australe.

Of these the two former occur in the lower greensand (neocomian) of Europe, and are most characteristic of the upper portion (Aptian of D'Orbigny); the third has been found in cretaceous beds of Australia, the exact horizon of which is not known.

Middle and upper cretaceous beds of India.—Excluding Cutch, there are but two areas, widely separated from each other, in which marine cretaceous rocks have hitherto been described as occurring in the Indian Peninsula. The most important of these is in the neighbourhood of Pondicherry and Trichinopoly in Southern India; the other is in the Narbada valley between Mandlesir and Broach. Fragments of sandstone containing cretaceous fossils have been found at Sripermatúr near Madras, but the rock has not been discovered in place. There is a third locality for marine fossils, which should, in all probability, be classed as cretaceous, in the neighbourhood of Ellore, but as the deposits are associated with outbursts of the Deccan trap, it will be best to treat of them in connexion with the rocks of that series. Cretaceous rocks are also found in Sind, the Panjáb Salt Range, and Spiti, north-east of the peninsular area; whilst to the north-east and east, beds of the same age occupy a considerable, but little known, area in Assam and Burma.

As the cretaceous rocks of Southern India have been carefully examined, and the magnificent series of fossils procured from them exhaustively described, they will first be noticed.

Cretaceous rocks of Trichinopoly and Pondicherry.—The occurrence of cretaceous rocks in Southern India was first observed in 1840 by Mr. Kaye of the Madras Civil Service, who, in company with Mr. Brooke Cunliffe and others, collected a large series of fossils, which were examined by Professor E. Forbes. The rocks near Pondicherry had, however, some years before attracted the notice of Mons. E. Chevalier, but no account of them was published until after the appearance of

Mr. Kaye's description. A collection of fossils from the neighbourhood of Pondicherry was examined by Mons. A. D'Orbigny, and referred to an upper cretaceous age. Professor E. Forbes, on the other hand, referred the beds of Trichinopoly and Verdachellam to the age of the upper greensand or gault, and the Pondicherry beds to the neocomian. It was shewn by Mr. H. F. Blanford that beds of two ages exist near Pondicherry, and he, following Professor Forbes, considered the lower of these or Valudayur beds neocomian and older than any of the Trichinopoly rocks, but the thorough examination of all the Southern Indian fossils by Dr. Stoliczka has proved that the general homotaxis is middle and upper cretaceous, and that the neocomian and oolitic forms, which led to a portion of the beds being originally classed as lower cretaceous, are less numerous than the middle cretaceous species with which they are associated. It was also found that the fauna of the Valudayur beds had more species than was at first supposed in common with the lowest group of the Trichinopoly area, and the two were consequently considered identical. The *Cephalopoda* of the lower beds comprise several species found in the gault of Europe, and the number was at first supposed to be larger than it proved on subsequent closer investigation; but as there are scarcely any representatives of gault forms amongst the very numerous and beautifully preserved *Gasteropoda* and *Lamellibranchiata* (*Pelecypoda*), the whole of the Southern Indian beds were finally referred by Dr. Stoliczka to an age not older than the upper greensand of England (cenomanian), and ranging thence to the upper chalk (senonian).

The rocks of cretaceous age in Southern India [1] occupy, with relation to older and newer formations, a very similar position to that of the outcrops of upper Gondwána beds farther to the northward. The cretaceous beds occur in the great plain which extends along the Coromandel Coast, from the north of the Godávari to Cape Comorin. They rest to the west upon the gneiss or occasionally upon small patches of the upper Gondwána (Rájmáhal) beds themselves; they have a low dip to the eastward, and are covered up on the east by tertiary beds, known as Cuddalore sandstones, and by the alluvium of the sea-coast. The cretaceous beds are exposed at the surface in three detached areas, separated from each other by the alluvial deposits of the Puniar and Vellaur rivers; of these areas the southern and largest, between the Vellaur and Coleroon rivers, is in the Trichinopoly district, and known as the Trichinopoly area. North

[1] For a complete description of the geology by Mr. H. F. Blanford, see Mem. G. S. I., Vol. IV, pp. 1–217. The fossils are described and figured in four volumes, comprising Series I, III, V, VI, and VIII of the "Palæontologia Indica," all by Dr. F. Stoliczka, with the exception of the *Belemnites* and *Nautili*, which are by Mr. H. F. Blanford. Some additional notes on the *Cephalopoda* are published in the Rec. G. S. I., Vol. I, p. 32.

of Vellaur are two much smaller exposures near Verdachellam and Pondicherry respectively, and named from those towns.

Area occupied.—The Trichinopoly area extends about 25 miles from north to south, and is of about the same breadth where widest, but it is very irregular in form. South of the Coleroon (the principal outlet of the river Cauvery) no cretaceous beds have hitherto been clearly traced, though representatives may perhaps occur south of Trichinopoly and east of Madura, but the southern boundary of the cretaceous area, north of the Coleroon, is chiefly formed by gneiss, and metamorphic rocks appear again to the south of the alluvial flat through which the river runs. To the northward, however, the cretaceous rocks disappear beneath the alluvium of the Vellaur river and re-appear north of the river at Verdachellam (Vriddachellam), forming the Verdachellam area, in which, however, only the highest cretaceous group is exposed, and even this is only visible at very few points. It occupies a tract of country about 15 miles long from north-north-east to south-south-west, by about 5 broad, with gneiss to the west and tertiary Cuddalore sandstone to the east. There is a second break in the rocks at the Panár river, and alluvium extends to the neighbourhood of Pondicherry, causing an interval of about 25 miles in the belt of cretaceous rocks before they reappear near Valudayur, 10 miles west by north from Pondicherry. Here they occupy a small tract of country about 12 miles long from north-east to south-west, by 6 miles broad, and only separated from the sea on the east by a band of Cuddalore sandstones 2 to 4 miles wide. To the west is a narrower strip of Cuddalore sandstone, beyond which the country consists of gneiss.

Sub-divisions.—In all three areas there appears to be a low dip to the east, the lowest beds appearing at the western boundary and higher groups succeeding in regular order to the eastward. Many of the dips seen in the rocks are, however, deceptive, being due to oblique lamination or false bedding, which prevails extensively throughout the series, and especially in the southern portion of the Trichinopoly area. In the Verdachellam and Pondicherry areas the rocks are ill seen, and the dips are less distinct, but there appears every probability that the same low dip prevails in the Pondicherry or Valudayur area; the direction is, however, south-east rather than east.

The cretaceous series in Southern India is divided into three groups, named in descending order Arialúr, Trichinopoly, and Utatúr. The following table taken from the "Palæontologia Indica[1]" exhibits Dr. Stoliczka's

[1] Ser. VIII, Introduction, p. ii. In the original there are several slight errors or misprints in the fossil names, and it is probable that the proof was not corrected by Dr. Stoliczka.

final views as to the representation by these groups of the European cretaceous sub-divisions:

South India.		England.	France.	Germany.
ARIALUR GROUP.	Zone of *Nautilus danicus* and *Ammonites ootacodensis*, *Ostrea pectinata*, and *O. ungulata*, *Gryphæa vesicularis*, *Inoceramus cripsii*, *Crania ignabergensis*.	Upper chalk	Senonian ...	Ober Quader.
TRICHINOPOLY GROUP.	Zone of *Ammonites peramplus*, *Pholadomya caudata*, *Modiola typica*, *Ostrea diluviana*, *Rhynconella compressa*.	Lower chalk	Turonian ...	Mittel Quader.
UTATUR GROUP.	Zone of *Ammonites rostratus* and *rotomagensis*, *Inoceramus labiatus*, *Exogyra suborbiculata* (*Gryphæa columba*), and *Terebratula depressa*.	Chalk marl and upper greensand.	Cenomanian or Tourtia.	Unter Quader, Unterer Quadersandstein, and Unterer Pläner.

Utatur group.—The Utatúr group derives its name from a large village 20 miles north-north-east of Trichinopoly. The beds composing the group are chiefly argillaceous; fine silts, calcareous shales, and sandy clays, frequently concretionary, and more or less tinted with ochraceous matter, prevail throughout the group, and in the southern portion of the area constitute almost the entire bulk of the deposit. North of the villages of Garudamangalam and Kauray, both in the neighbourhood of Utatúr, limestone bands become intercalated in the lower or western part of the group, and sands, grits, and conglomerates in the upper or eastern part, these changes in mineral character being accompanied by a great enrichment of the fauna in the first case and an impoverishment in the other. Conglomerates are of very rare occurrence in the lower beds. Gypsum occurs in most of the argillaceous strata, and is to a certain extent characteristic of the sub-division. The dips are often irregular, and apparently due to the original deposition of the beds on shelving banks. This irregularity of dip renders it impossible to form any trustworthy estimate of the thickness attained by the group as a whole; it may, however, be roughly estimated as probably not less than 1,000 feet.

At the base of the Utatúr group, there are, in several places, large masses of coral reef limestone, resting sometimes on the plant beds (upper Gondwána), but more frequently on the gneiss, and occasionally on the

lowest beds of the Utatúr group itself. The rock is a nearly pure pale-coloured limestone, compact and homogeneous, but often with a flaggy structure, and frequently irregularly banded with white streaks, which, on weathered surfaces, exhibit the corals of which they are composed. The mass of the rock also sometimes abounds in corals, but more frequently no organic structure can be traced. In lithological character this rock precisely resembles the coral reef limestone of the present day, as described by Darwin, Dana, Jukes, and other observers.

The usual position of this limestone is at the base of the Utatúr group, resting upon older rocks. The coral reefs appear to have been frequently exposed to denudation during the deposition of the later Utatúr beds, amongst which, in places, calcareous bands are found, apparently derived from the waste of the reefs. The coral limestone now remains in the form of small isolated patches, scattered along the western and southern margins of the cretaceous beds. In one locality, however, close to the village of Cullygoody, on the southern boundary of the cretaceous area, and 20 miles north-east of Trichinopoly, by far the largest outcrop of the limestone in the area occurs at the base of the Trichinopoly group. This outcrop is of considerable breadth, and extends, with one or two breaks, for about 6 miles. From an examination of all the circumstances, however, it has been satisfactorily ascertained that this outcrop also belongs to the Utatúr group, and that the Trichinopoly group rests unconformably upon it.

The coral reefs appear to have been scattered over the sea bottom in shallow water, and probably along the coast, at the commencement of the period during which the cretaceous deposits of Southern India were formed. The remaining beds of the Utatúr group were probably deposited in water of moderate depth, and some of them appear to have accumulated on submarine banks formed possibly by tidal channels. Hence the false bedding so prevalent in the rocks. The coarser constituents of the rocks to the northward appear to indicate that the current which brought the sediment flowed from that direction, and the occurrence of littoral forms of mollusca in greater abundance throughout the northern parts of the area may be accounted for in the same manner. The beds in the southern portion of the Utatúr area appear to have been formed of fine silt deposited in a bay where the force of the current was less than to the northward, and the fossils which occur are mostly the remains of pelagic animals, such as *Belemnites*, or a few *Ammonites*, chiefly of the *Cristati* group, or else peculiar forms of *Vermetidæ* (*Tubulostium discoideum* and *T. callosum*), which probably lived in the mud. The *Ammonites* and *Nautili*, which are numerous to the northward, are scarce in the southern portion of the area. Cycadeaceous (exogenous)

fossil wood, sometimes bored by *Teredo* and other *Pholadidæ*, abounds in certain parts of the group. On the whole, there appears every reason to believe that the Utatúr beds were formed in the neighbourhood of a coast line.

Distribution.—The distribution of the Utatúr beds in the Trichinopoly district is very simple. They form the western portion of the cretaceous area throughout: their outcrop being in general from 3 to 5 miles broad, except to the northward, where it diminishes in consequence of the beds being overlapped by those of the next group, till, in the northern portion of the tract at the village of Olapaudy, the breadth of the Utatúr outcrop does not exceed half a mile. At the extreme northern point of the area, both the Utatúr and Trichinopoly groups are completely overlapped by the uppermost subdivision.

The Utatúr beds are not represented in the Verdachellam area, but they reappear, as already mentioned, near Pondicherry. Here the beds formerly classed as the Valudayur group, and considered neocomian by Forbes, but which were shewn by Stoliczka to contain several species of fossils common to the Utatúr group, consist chiefly, like the strata near Utatúr, of argillaceous beds, sandy shales and sands, with occasional bands of limestone and calcareous concretionary nodules. Amongst the lowest beds seen conglomerates occasionally occur; but the most characteristic band is composed of dark-grey compact limestone in large nodules, sometimes highly fossiliferous; *Baculites vagina* (Pl. XIII, fig. 4) being the commonest fossil.

The area occupied by the Utatúr or Valudayur beds near Pondicherry extends from Valudayur for about 9 miles to the north-east and is about 4 miles broad. The beds are not seen to rest upon any older formation; north and south the country is covered with alluvium; to the eastward the Utatúr beds disappear beneath the Arialúr group, and to the westward beneath the Cuddalore sandstones of Trivicary. The beds to the westward appear to be the lowest, and there is a dip to the eastward.

Palæontology.—The fauna of the Utatúr group is very rich, no less than 297 species of *Invertebrata* having been described from it. It has yielded an especially large number of *Cephalopoda*, 109 species, of which 95 have not been met with in the Trichinopoly or Arialúr group. Of these 109 species 27 are known to occur in Europe or elsewhere out of India, and although the majority are distinctly and characteristically middle cretaceous forms, 3 are, in Europe, neocomian species, *viz.*, *Nautilus neocomiensis*, *Ammonites velledæ*, and *A. rouyanus*, whilst no less than 9 are found in the gault, several of the latter

ranging, however, into the upper greensand (cenomanian). Amongst the forms which are not European, the most remarkable are 3 species belonging to the section of *Ammonites* known as *Globosi*, which, amongst European rocks, are especially characteristic of the triassic period. A very large proportion of the *Cephalopoda* were collected in the neighbourhood of two villages, Odium and Maravattúr, on the road from Perambalúr to Arialúr, and about 12 miles north-east of Utatúr.

The *Gasteropoda* comprise, on the other hand, only 43 species, a number far inferior to that found in each of the other groups; the majority are littoral forms. The *Lamellibranchiata* (*Pelecypoda*) are 79 in number; the *Brachiopoda* 9, *Echinodermata* 10, and corals 42, with one species of sponge and one annelid. The forms found also in other countries belong almost without exception to the upper greensand (cenomanian) or higher groups, thus presenting a remarkable difference from the *Cephalopoda*, in which gault forms are so largely represented. The only fossils, besides the *Mollusca*, which are of much importance, are the corals, which, from the prevalence of reefs at the base of the group, are superbly represented, no less than 42 species being known to occur, belonging to 23 genera, *viz.*, *Caryophyllia*, *Platycyathus*, *Trochosmilia*, *Lophosmilia*, *Epismilia*, *Psammosmilia*, *Stylina*, *Thecosmilia*, *Holocœnia*, *Astrocœnia*, *Mycetophyllia*, *Stelloria*, *Heliastræa*, *Placastræa*, *Isastræa*, *Latimæandra*, *Thamnastræa*, *Dimorphastræa*, *Comoseris*, *Thecoseris*, *Eupsammia*, *Coscinaræa*, and *Heliopora*.

The following is a list of all the most common and important species of *Invertebrata* found in the Utatúr group, those forms which are especially abundant and characteristic being marked by an asterisk, thus*. Some species of comparatively rare occurrence in India are included, because they are well-known European forms, and therefore of importance to shew the relations of the group. Some others are remarkable, as shewing the presence of genera not found elsewhere in cretaceous rocks. All kinds found also in Europe or in other continents besides Asia are marked *e*, and the name of the formation or formations in which they are found is appended.

[1] All the details of the cretaceous fauna are from the four volumes of the "Palæontologia Indica" by Dr. Stoliczka. It was the author's intention after completing the work to have gone over the cretaceous country in Southern India, which he had never visited; and had he lived to examine the beds, much that is now obscure would doubtless have been cleared up, and the position of all the fossils accurately determined. So far as has been possible, all fossils of doubtful origin are omitted in the lists given. Amongst such large collections as those from Southern India, it is almost impossible to avoid some errors of locality if the collector is not the describer.

CEPHALOPODA.

BELEMNITIDÆ—
- * *Belemnites fibula.*
- e * *B. semicanaliculatus*, aptian to lower chalk.
- *B. seclusus.*

NAUTILIDÆ—
- e *Nautilus neocomiensis*, neocomian.
- *N. huxleyanus.*
- *N. ootatoorensis.*
- e * *N. pseudo-elegans*, neocomian.

AMMONITIDÆ—
- e * *Ammonites rostratus* (*A. inflatus*, Sow.), middle cretaceous.
- *A. siva.*
- e * *A. rotomagensis*, Pl. XIII, fig. 1, middle cretaceous.
- e *A. navicularis*, cenomanian; lower chalk.
- e * *A. mantelli*, gault; cenomanian.
- *A. vicinalis.*
- e *A. dispar*, cenomanian.
- *A. garuda* (*A. indra*).
- e *A. subalpinus*, gault.
- e *A. velledæ*, neocomian; middle cretaceous.
- e *A. rouyanus*, neocomian.
- *A. diphylloides.*
- *A. rudra.*
- *A. xetra.*
- *A. telinga.*
- *A. yama.*
- *A. durga.*
- e * *A. timothianus*, gault; grés vert.
- e *A. latidorsatus*, aptian; gault; grés vert.
- *A. madraspatanus.*
- *A. cala.*
- *A. sacya.*
- *A. kayei.*
- *A. papillatus.*
- *Scaphites similaris*, Stol. (*S. æqualis*, Sow. *apud* Stoliczka, *olim.*).
- e *S. obliquus*, middle cretaceous.
- e *Anisoceras armatum*, middle cretaceous.
- *A. rugatum.*
- *A. indicum.*
- e *Turrilites bergeri*, gault.
- e *T. gressleyi*, gault.
- c *T. tuberculatus*, gault.
- e *T. costatus*, Pl. XIII, fig. 3, gault to lower chalk.
- *Hamites problematicus.*
- *Hamulina sublævis.*
- e *Ptychoceras gaultinum*, gault.
- * *Baculites vagina*, Pl. XIII, fig. 4.
- e *B. gaudini*, gault.

GASTEROPODA.

ALATA—
- e *Alaria parkinsoni*, gault; cenomanian.

VOLUTIDÆ—
- *Ficulopsis pondicherriensis.*

PYRAMIDELLIDÆ—
- e *Nerinæa incavata*, turonian.

TURRITELLIDÆ—
- e *Turritella nerinæa*, senonian.
- e *T. nodosa*, cenomanian.

VERMETIDÆ—
- * *Tubulostium discoideum.*
- * *T. callosum.*

LITTORINIDÆ—
- *Littorina attenuata.*

NATICIDÆ—
- * *Tylostoma ootatoorense.*
- *Euspira spissata.*

TROCHIDÆ—
- *Delphinula annularis.*

PLEUROTOMARIIDÆ—
- *Pleurotomaria glabella.*
- *Leptomaria indica.*

ACTÆONIDÆ—
- *Actæonina columnaris.*
- *Trocactæon cylindraceus.*
- e *Avellana elongata*, cenomanian.

DENTALIIDÆ—
- *Antale glabratum.*

LAMELLIBRANCHIATA.

PHOLADIDÆ—
Teredo partita, and two other species.
Martesia tundens.
Parapholas mersa.

GASTROCHÆNIDÆ—
Rocellaria guttula.

MYIDÆ—
Corbula minima.

ANATINIDÆ—
Corimya pertusa.

SAXICAVIDÆ—
Saxicava tenella.

CARDIIDÆ—
Protocardium altum.
Fragum præcurrens.

LUCINIDÆ—
Lucina fallax.

NUCULANIDÆ—
Nuculana socialis.

ARCIDÆ—
Trigonoarca gamana.

AVICULIDÆ—
Aucella parva.
Inoceramus geinitzianus.
e *I. labiatus*, middle cretaceous.

RADULIDÆ—
Radula (*Limatula*) *persimilis.*

PECTINIDÆ—
Pecten verdachellensis.
P. (*Syncyclonema*) *obovatus.*
e *Vola lævis*, cenomanian.

SPONDYLIDÆ—
Plicatula sessilis.
Spondylus subcostulatus.

OSTRÆIDÆ—
e *Exogyra haliotoidea*, middle cretaceous.
e *E. costata*, upper cretaceous.
e *E. suborbiculata* (*Gryphæa columba*, auct.), middle cretaceous.
e *E. canaliculata*, middle cretaceous.
e *Gryphæa vesiculosa*, ditto.
e *Ostrea* (*Alectryonia*) *diluviana*, ditto.
e *O.* (*A.*) *carinata*, ditto.

BRACHIOPODA.

e *Terebratula depressa*, cenomanian (? and neocomian).
e *Terebratula obesa*, cenomanian; turonian.

ECHINODERMATA.

Hemiaster inæqualis.
Cassidulus emys.
Cassidulus planatus.
e *Cidaris hirudo*, cenomanian.

ANTHOZOA.

e *Trochosmilia tuba*, turonian.
Stylina multistella.
Holocænia ramosa.
* *Astrocænia retifera.*
A. reussiana.
Isastræa expansa.
I. siva.
I. cyathina.
Thamnastrea hieroglyphica.
Eupsammia varians.

SPONGIOZOA.

e *Siphonia pyriformis*, cenomanian.

Trichinopoly group.—The Trichinopoly or middle group of the Southern Indian cretaceous series derives its name from the district of Trichinopoly, to which it is, so far as present exploration extends, entirely restricted. To the south it consists chiefly of sands and clays,

very irregularly bedded, with a few bands of limestone and some conglomerates, and it differs lithologically only in one important respect, which will be described presently, from the Utatúr group. North of the neighbourhood of Alandanapuram and Garúdamangalam. east of Utatúr, regular bands of shell-limestones become intercalated in the lower beds of the deposit, and to the northward the whole group is composed of regularly stratified alternations of sand, sandy clays, and shales, with bands of shell-limestone, calcareous grit and conglomerate.

The peculiarity just mentioned by which both the Arialúr and Trichinopoly beds in the southern part of the cretaceous area are distinguished from the Utatúr consists in the occurrence of granite pebbles in considerable quantity in the gravels and conglomerates of the two former, whilst none are found in the lower sub-division. In the Utatúr group the materials of the few conglomeratic or gravelly beds which occur are derived either from the gneiss or from the coral reef limestone, whilst in the two upper groups conglomerates are more frequently met with, and loose masses of unstratified gravel and beds of rolled pebbles, almost entirely composed of granitic materials, and resembling the shingle of a sea-beach, are of common occurrence. The source of the granite pebbles was evidently the broad belt of granitic rocks which forms the southern boundary of the cretaceous area, and divides it from the alluvium of the Cauvery throughout the greater portion of its extent; and the necessary inference is, that this band of rock was in all probability beneath the sea during the deposition of the Utatúr beds, and that it was elevated above the water in the interval between the Utatúr and Trichinopoly periods.

The Trichinopoly beds are, even more characteristically than the Utatúrs, the littoral deposits of a shallow sea. This is proved, not only by the frequent occurrence of coarse sediment and the great irregularity of the deposits in part of the area, but by the abundance of fossil wood, almost exclusively exogenous, and apparently Cycadeaceous. Trunks of trees are met with of great size, as much as 3 feet in diameter and 60 feet in length; much of the wood being perforated by boring mollusca.

The shell-limestone of Garúdamangalam and other places is a very fine hard bluish-grey translucent rock, usually abounding in beautifully preserved shells, both *Gasteropoda* and *Lamellibranchiata*, which retain their original polish, and occasionally even the coloration of their surfaces. This rock is largely quarried for ornamental purposes, and is known as "Trichinopoly marble:" it has yielded a considerable proportion of the fossils found in the group. The limestone occasionally contains pebbles of granite or fragments of fossil wood, either of which is sufficient to distinguish it, even when it is unfossiliferous, from the Utatúr limestones.

The beds of the Trichinopoly group are unconformable to the Utatúrs, upon which they rest throughout the greater part of the area, the evidence of unconformity not being confined to overlap, but depending chiefly upon the proof, afforded by the rocks at the southern edge of the area, that the Utatúr beds had been disturbed and faulted, probably at the period of upheaval of the granitic band already mentioned, before the deposition of the Trichinopoly formation. Elsewhere also the Trichinopoly beds in places rest upon a denuded surface of Utatúrs. There is also a great change in the fauna. In the southern portion of their range the Trichinopoly beds rest partly upon the coral reefs, which have been already shewn to be some of the lowest beds of Utatúr age, and partly on the metamorphics, a considerable portion of the boundary being formed by the granitoid rock so frequently mentioned already.

The present group, like the Utatúr, is so irregularly bedded, and the dips seen are so frequently those of original deposition, that no trustworthy estimate of the thickness can be formed. The general inclination is to the eastward; the average breadth of the outcrop is nearly the same as that of the Utatúr beds, and the same minimum thickness, *viz.*, 1,000 feet, may be assumed; the general dip of the bedding in the more regularly stratified portion of the group to the northward is, however, lower than in the underlying group, averaging about 6°. The beds thin out greatly to the northward, and are at length completely overlapped by the Arialúrs.

Distribution.—It has already been stated that the Trichinopoly group is confined, so far as is at present known, to the Trichinopoly area. Within that area it forms a second belt east of that formed by the Utatúr group, and extending similarly from south-south-west to north-north-east. The Trichinopoly outcrop is, however, broader in the southern half of the area, where it is about 4 miles across, than in the northern half, where it is in no place more than 2 miles wide. It thins out and disappears completely about 2 miles south of the place where the Utatúrs are similarly overlapped by the Arialúr beds. Along the southern boundary of the Utatúr area, several outliers of Trichinopoly beds are found, resting partly on the Utatúrs and partly on the gneiss, and occasionally overlying the faulted boundaries between the two formations. These small outliers, one of which, south of Tripatúr, forms the south-eastern corner of the whole area, are composed of coarse sands and conglomerates, usually unfossiliferous, but occasionally containing *Chemnitzia undosa* and other characteristic Trichinopoly fossils, and the materials of which they are formed are derived chiefly from the metamorphic rocks, but partly from the denudation of the Utatúr beds.

Palæontology.—The fauna of the Trichinopoly group, although not quite so rich as that of the Utatúr beds, affords a full illustration of the life existing at the period; 186 species of *Invertebrata* having been described from these beds by Dr. Stoliczka. The *Cephalopoda* are comparatively poorly developed, only 23 species having been detected, and of these but 10, of which four are European, are in India peculiar to the group. All the *Cephalopoda* identified belong to the two genera *Nautilus* and *Ammonites,* the non-discoid Ammonitoid genera, such as *Anisoceras, Scaphites, Turrilites,* &c., so largely represented in the Utatúr group, as well as the *Belemnites,* so abundant in the lower subdivision, being apparently wanting in the Trichinopoly beds. The *Rotomagenses* Ammonites, so characteristic of the lowest cretaceous sub-division in Southern India, are also wanting in the higher groups, with one doubtful exception. A few forms, usually associated with older strata, still survive, however, such as *Ammonites menu,* belonging to the *Armati,* a jurassic group, *A. koluturensis* of the *macrocephalus* group, allied to such oolitic species as *A. macrocephalus* and *A. herveyi,* and *A. theobaldianus,* one of the *Planulati* allied to upper jurassic forms such as *A. biplex.* Most of the types found are, however, characteristically upper cretaceous.

On the other hand, *Gasteropoda,* comprising 86 species, are much more abundant than in the Utatúr group; *Lamellibranchiata* (66 species) being rather less numerous. There are but 5 *Brachiopoda* and 6 corals, whilst no *Echinodermata* have been recognised. The *Gasteropoda* include several siphonostomate genera, rare in the older rocks, and not found in the Utatúr beds; the number increases greatly in the next higher sub-division, that of Arialúr. The whole fauna exhibits a mixture of upper and middle cretaceous forms, and appears fairly to represent the lower chalk of England or the turonian of continental geologists.

The following list of the most important species is similar to that already given from the Utatúr group, an asterisk * denoting the most abundant and characteristic forms, *a* those found in South Africa, and *e* those found in Europe or elsewhere out of Asia:—

CEPHALOPODA.

NAUTILIDÆ—
- e * *Nautilus elegans,* middle cretaceous.
- * *N. huxleyanus.*

AMMONITIDÆ—
- e *Ammonites subtricarinatus,* middle cretaceous; senonian.
- * *A. sugata.*
- e *A. guadaloupæ,* middle cretaceous.
- *A. koluturensis.*
- e *A. peramplus,* middle cretaceous; turonian; senonian.
- * *A. planulatus.*
- e *A. timotheanus,* gault; grés vert.
- * *A. theobaldianus.*

GASTEROPODA.

ALATA—
* *Pugnellus contortus.*
P. granuliferus.
a *P. uncatus.*
* *Aporrhais securifera*, Pl. XIII, fig. 5.
e *Alaria parkinsoni*, gault; greensand.
e *A. papillionacea*, turonian.
Rostellaria palliata.

CYPRÆIDÆ—
Cypræa (Luponia) newboldi.
C. (Aricia) ficulina.

PLEUROTOMIDÆ—
e *Pleurotoma subfusiformis*, turonian.

CONIDÆ—
Gosavia indica (perhaps from Arialúr beds).

VOLUTIDÆ—
Scapha attenuata.
e * *Fulguraria elongata*, turonian; cenomanian.
Athleta purpuriformis.
Volutilithes accumulata.
Volutomitra canaliculata.

FASCIOLARIIDÆ—
Latirus reussianus.
a * *Fasciolaria rigida.*

MURICIDÆ—
Hemifusus cinctus.
* *Neptunea excavata.*
e *Tritonidea requieniana*, middle cretaceous.
a *T. trichinopolitensis.*
a * *Pollia pondicherriensis.*
Trophon oldhamianum.

PURPURIDÆ—
* *Rapa cancellata.*
Rapana tuberculosa.

TRICHOTROPIDÆ—
e *Trichotropis konincki*, senonian.

CANCELLARIDÆ—
Narona eximia.

CERITHIIDÆ—
Cerithium hispidulum.

TURRITELLIDÆ.
Arcotia indica.
* *Turritella (Zaria) brantiana.*
e *T. (Torcula) affinis*, senonian

LITTORINIDÆ—
Littorina inconstans.
L. acicularis.

RISSOIDÆ—
Rissoa oldhamiana.
Keilostoma politum.

EULIMIDÆ—
a * *Chemnitzia undosa.*
a *Euchrysalis gigantea.*

NATICIDÆ—
* *Euspira mariæ.*
e * *Ampullina bulbiformis*, turonian; senonian.

TROCHIDÆ—
e *Ziziphinus geinitzianus*, turonian.

ACTÆONIDÆ—
Bullina alternata.
Actæon seminalis.
A. turriculatus.
Trochactæon cylindraceus.

DENTALIIDÆ—
Dentalium crassulum.

LAMELLIBRANCHIATA.

MYIDÆ—
Corbula parsura.
Poromya superba.

ANATIDÆ—
Corimya oldhamiana.
e *Pholadomya caudata*, upper and middle cretaceous.
P. radiatula.

SAXICAVIDÆ—
* *Panopæa orientalis.*

SOLENIDÆ—
Siliqua lunata.

TELLINIDÆ—
Tellina (Palæomæra) inconspicua.

VENERIDÆ—
Cyprimeria oldhamiana.
e *Eriphyla lenticularis*, upper cretaceous.

GLOSSIDÆ—
* *Cyprina forbesiana.*

LAMELLIBRANCHIATA—(*contd.*)

CARDIIDÆ—
Cardium (Trachycardium) incomptum.
e * *Protocardium hillanum*, Pl. XIII, fig. 7, cenomanian to senonian.
Protocardium pondicherriense.

TRIGONIDÆ—
e *Trigonia scabra*, Pl. XIII, fig. 8, upper cretaceous.
T. tuberculifera.
T. semiculta.

ARCIDÆ—
* *Trigonoarca trichinopolitensis.*

MYTILIDÆ—
e * *Modiola typica*, turonian.

PINNIDÆ—
Pinna complanata.
P. arata.

AVICULIDÆ—
Inoceramus geinitzianus.

PECTINIDÆ—
e *Pecten (Camptonectes) curvatus*, upper and middle cretaceous.

SPONDYLIDÆ—
Plicatula multicostata.
Spondylus calcaratus.

OSTRÆIDÆ—
e *Ostrea (Alectryonia) diluviana*, middle cretaceous.
e *O. (A.) carinata*, middle cretaceous.

BRACHIOPODA.

e *Rhynconella compressa*, upper cenomanian; turonian.
* *R. plicatiloides.*
e *Terebratula biplicata*, var. *Dutempleana*, middle cretaceous.

ANTHOZOA.

e *Trochosmilia inflexa*, turonian.
e *Isastræa morchella*, turonian.

Arialur group.—The name of the highest group of the South Indian cretaceous series is derived from the town of Arialúr, which lies about 34 miles north-east of Trichinopoly, and 24 miles almost due north from Tanjore, and is situated nearly in the middle of the comparatively large expanse of Arialúr beds in the Trichinopoly district. The country occupied by the beds of this group is much covered with cotton soil, and sections are even rarer than in the two lower cretaceous subdivisions.

The Arialúr beds are more sandy than the two lower groups, and more uniformly bedded, the beds being thick and homogeneous, and consisting principally of white unfossiliferous sands and grey argillaceous sands, with casts of small fossils. Beds of calcareous grit and nodular calcareous shales are found towards the base, and again in the upper portion of the group, and constitute two highly fossiliferous zones, separated by a considerable thickness of deposits, in which fossils are rare or wanting, although some interesting remains of a *Megalosaurus* were found in one of the beds. With the uppermost beds a band of flints is associated. There is a marked difference between the fossils of the upper and lower zones in Trichinopoly, and it appears very probable that further examination of the rocks, now that the fossils have been compared and determined, would justify the separation of this group into

two—a probability which was pointed out by Mr. H. F. Blanford at the time of the original survey, although not shewn on the map, nor applied in the discrimination of the fossils, because of the doubts which remained as to the distinction of the two sub-divisions in the Pondicherry area, where the fossils of both upper and lower Arialúr beds appear to occur together. Conglomerates are of rare occurrence in the Arialúr group, though a coarse bed is found in places near the base, and, except close to the southern boundary, there is but little irregularity in the bedding. The constituents of the Arialúr beds were derived chiefly from the metamorphic rocks, and amongst others from the granitic band to the southward, but a portion of the sediment must have been furnished by the waste of some of the older cretaceous groups, probably the Utatúrs.

The above description of the lithological characters is principally taken from the beds near Arialúr (Trichinopoly district), but it is also to a great extent applicable to the rocks seen near Verdachellam and Pondicherry. In both localities, the Arialúr deposits are chiefly represented by sands or sandy clays, and by beds of arenaceous limestone or calcareous sandstone at the base of the group. The strata appear to thin out to the northward, and it is far from clear whether the uppermost fossiliferous zone extends in that direction, although some of its characteristic fossils, such as *Nautilus danicus*, occur abundantly near Pondicherry. It has not, however, hitherto been found practicable to determine whether a distinct upper zone exists near Pondicherry or whether representatives of the upper fauna occur in beds of lower horizon than those in which the same species are found near Arialúr.

There is consequently some obscurity concerning the relations of the beds belonging to the Arialúr group amongst themselves, and this difficulty is complicated by the circumstance that there is in many places an apparent passage from the Trichinopoly group into the Arialúr beds; the rocks being similar in mineral character near the junction, and the fossils being chiefly forms which appear to range from one group into the other. It is highly probable that further examination of the ground, which, as has been already noticed, is so much concealed by superficial accumulations that the different groups can frequently only be traced by their fossils, would shew that either the number of groups or of palæontological zones must be increased, or else that, in some cases, fossils, supposed to have been procured from the Trichinopoly group, have really been derived from the Arialúr, and *vice versá*.

Distribution and relations to lower groups.—The area occupied by the Arialúr beds in the eastern portion of the Trichinopoly tract

amounts to about 200 square miles, or more than that covered by both the other sub-divisions together; the outcrop where broadest near Arialúr is about 16 miles wide, and extends for 26 miles from north to south.

The Arialúr beds also occupy the greater portion of a tract 16 miles long by 5 miles broad near Verdachellam, and another about 12 miles long from south-west to north-east, by 2 miles broad, west of Pondicherry, whilst a very small exposure of them occurs close to the coast 10 miles north of Pondicherry, and another still smaller 3 miles farther north.

The lowest fossiliferous zone is found resting upon the Trichinopoly beds throughout the western portion of the Arialúr area in the Trichinopoly district, and the same zone appears to be also represented in the Verdachellam and Pondicherry exposures. The great bulk of the outcrop in all three tracts appears to consist of the thick sands, with but few determinable fossils, forming the middle portion of the formation, whilst the upper fossiliferous beds are only seen north of Arialúr, near the villages of Sainthoray, Ninnyur, and other places farther north, in the long strip of cretaceous rocks forming the north-eastern extremity of the Trichinopoly area, between the Cuddalore sandstones to the east and the alluvium of the Vellaur valley to the west, and extending as far as the Vellaur river about a mile north of Aulathor.

Although the thickness of the Arialúr group can be estimated with a nearer approach to probability than in the case of the two lower cretaceous formations, the estimate is still far from accurate. The dip of the beds is very low, rarely exceeding 2° to 3°, the general inclination being north-east, and the whole of the beds in all probability do not exceed 1,000 feet in Trichinopoly. Near Verdachellam they appear to be very thin, and in the neighbourhood of Pondicherry they are too obscurely exposed for any estimate of their thickness to be attempted. There is an apparent diminution of thickness to the northward as in the other groups, but this attenuation appears to be greatest near Verdachellam, and takes place less rapidly farther north, even if the beds are not thicker in that direction.

The Arialúr beds, as has been already stated, frequently appear to pass into the Trichinopoly group at their base. They, however, overlap the lower groups both to the north and south, and there is, in places, an appearance of unconformity where they rest upon the Trichinopoly beds, nor is it easy to understand the very rapid diminution in the thickness of the latter to the northward without supposing that they had been partially denuded in pre-Arialúr times.

As was noticed in the description of the Utatúr group, the Arialúr beds rest upon the Utatúrs for a distance of rather more than 2 miles in the northern part of the Trichinopoly area, and still farther north the former were deposited directly on the gneiss. They also rest on the gneiss throughout the whole breadth of their outcrop in the south of the Trichinopoly area, and in the Verdachellam cretaceous tract, whilst in the neighbourhood of Pondicherry they are deposited to the eastward on the Valudayur representatives of the Utatúr group, and to the westward no beds are seen beneath them, the Cuddalore sandstones overlapping them completely. Throughout the Trichinopoly and Verdachellam areas, the Arialúr beds disappear to the eastward beneath the Cuddalore sandstones, which are unconformable to the cretaceous beds, and the latter are covered up by alluvial deposits in the valleys of the Vellaur and Panar rivers intervening between the three areas, and also to the north of the Pondicherry area.

The Arialúr beds appear to have been chiefly deposited in a tranquil sea of small depth, although the deposits are less characteristically littoral than those of the Trichinopoly group, and the evidence of the neighbourhood of land afforded by the occurrence of fossil wood is less abundant.

Palæontology.—The invertebrate fauna of the Arialúr group exceeds in richness even that of the Utatúr beds, no less than 365 species having been detected in the uppermost sub-division of the cretaceous rocks of Southern India. The *Cephalopoda* comprise 36 species, *Gasteropoda* 138, *Lamellibranchiata* 117, *Brachiopoda* 12, *Bryozoa* 23, *Echinodermata* 26, *Anthozoa* 10, *Foraminifera* 1, and *Vermes* 2. It is highly probable that this large number may be due partly to the circumstance that the Arialúr deposits comprise two groups differing somewhat in age. The lower fossiliferous beds, from which the bulk of the fossils have been procured, correspond very fairly with the Senonian beds of France and the upper chalk with flints of England. From this horizon all the *Cephalopoda* found in the formation have been derived, with the exception of *Nautilus danicus*, which was only observed in the upper beds of Ninnyur, &c., in the Trichinopoly area, although some specimens were obtained, apparently from a lower horizon, near Pondicherry. The fauna of these upper beds will be noticed separately; the following remarks apply to the remainder of the group.

In the Arialúr beds, as in the lower sub-divisions, there are some forms of *Cephalopoda* which are in Europe characteristic of older beds. These comprise two gault species of *Nautilus*, *N. bouchardianus* and *N. clementinus*, *Ammonites menu*, found also in the lower groups, and

belonging to the Jurassic section of *armati*, *A. velledæ*, a lower and middle cretaceous form in Europe, two *macrocephali*, *A. deccanensis*, and *A. arrialoorensis*, and one of the *Planulati*, *A. theobaldianus*. In the other classes of Mollusca, very few older forms occur, and the great majority of the species common to Europe are found in the upper cretaceous beds of England, France, and Germany.

The most striking peculiarity of the Arialúr fauna is the great abundance of *Gasteropoda*, and especially of the carnivorous prosobranchiate forms, which, as is well known, appear to replace in tertiary and recent seas the *Cephalopoda* of the older periods. Several genera not previously known from cretaceous beds have been detected in the Arialúr group, and the *Cypræidæ* and *Volutidæ* are especially well represented. The *Lamellibranchiata* are also very numerous, whilst all the *Bryozoa* and the great majority of the *Echinodermata* hitherto found in the cretaceous beds of Southern India have been obtained in the highest sub-division. Lower forms of animals are but poorly represented. Amongst the *Vertebrata*, the only important species is a *Megalosaurus*,[1] of which a tooth was found in the middle beds of the deposit, together with a number of bones which, however, could not be extracted in a sufficiently perfect state for determination. The tooth closely resembles that of *M. bucklandi*, found in the Stonesfield slate and Portland oolites of England, and the occurrence of this genus in the upper cretaceous beds of India is of peculiar interest, because in Europe it only ranges from the lias to the wealden. In this instance, as in several others, the land fauna appears to have differed more from that which inhabited distant parts of the earth than the marine fauna did.

The following list of the most important fossils is similar to those of the Utatúr and Trichinopoly groups, and the distinctive marks are the same, an asterisk signifying abundance, and *e* that the fossil occurs also in Europe or elsewhere beyond the limits of Asia :—

CEPHALOPODA.

NAUTILIDÆ—
- *e* *Nautilus bouchardianus*, gault.
- * *N. sphæricus*.
- *e* *N. clementinus*, gault.
- *N. trichinopolitensis*.

AMMONITIDÆ—
- * *Ammonites sugata*.
- *e* * *A. gardeni*, upper cretaceous.
- *e* *A. ootacodensis*, upper cretaceous.
- *e* *A. velledæ*, neocomian to cenomanian.
- * *A. arrialoorensis*.
- * *A. madrasinus*.
- *A. theobaldianus*.
- *Helicoceras indicum*.
- *Baculites vagina*.

[1] Mem. G. S. I., Vol. IV, pp. 128, 139; Rec. G. S. I., X, p. 41.

GASTEROPODA.

ALATA—
Rostellaria palliata.
CYPRÆIDÆ—
Cypræa cunliffei.
e *C. kayei*, senonian.
Erato veraghoorensis.
OLIVIDÆ—
Dipsacus vetustus.
DOLIIDÆ—
Oniscia costellata.
PLEUROTOMIDÆ—
Cythara cretacea.
VOLUTIDÆ—
* *Volutilithes septemcostata.*
Turricula arrialoorensis.
FASCIOLARIIDÆ—
Fasciolaria carnatica.
F. assimilis.
MURICIDÆ—
e *Neptunea rhomboidalis*, turonian; senonian.
TRITONIIDÆ—
Hindsia eximia.
Tritonium gravidum.
Lagena secans.
BUCCINIDÆ—
Nassa arrialoorensis.
PURPURIDÆ—
Tudicla eximia.
CANCELLARIIDÆ—
Cancellaria (*Euclia*) *breviplicata*, and 3 other species of *Cancellaria.*
CERITHIIDÆ—
e *Cerithium inauguratum*, senonian.
* *C. arcotense.*
e *C. trimonile*, gault.
C. scalaroideum.
C. (*Sandbergia*) *antecedens.*
TURRITELLIDÆ—
Turritella (*Torcula*) *pondicherriensis.*
e *T.* (*Zaria*) *multistriata*, turonian.
SCALIDÆ—
e *Scala subturbinata*, senonian.
VERMETIDÆ—
e * *Burtenella concava*, chalk.
SOLARIIDÆ—
Solarium karapaudiense.
S. vylapaudiense.
LITTORINIDÆ—
Littorina crassitesta.
RISSOIDÆ—
e *Rissoina acuminata*, senonian.
Keilostoma subulatum.
NATICIDÆ—
Euspira pagoda.
VELUTINIDÆ—
Velutina orientalis.
TECTURIDÆ—
Helcion corrugatum.
NERITIDÆ—
Neritina (*Velates*) *decipiens.*
Nerita divaricata.
UMBONIIDÆ—
Teinostoma cretaceum.
TROCHIDÆ—
Tectus tamulicus.
e *Ziziphinus geinitzianus*, turonian.
e * *Solariella radiatula*, senonian.
PLEUROTOMARIIDÆ—
* *Leptomaria indica.*
ACTÆONIDÆ—
* *Avellana scrobiculata*, Pl. XIII, f. 6.

LAMELLIBRANCHIATA.

TELLINIDÆ—
Tellina scitulina.
VENERIDÆ—
Cytherea lassula.
GLOSSIDÆ—
Veniella (*Venilicardia*) *obtruncata.*
CARDIIDÆ—
Cardium (*Trachycardium*) *exulans.*
HIPPURITIDÆ—
Radiolites mutabilis.
CRASSATELLIDÆ—
e *Crassatella macrodonta*, upper cretaceous.
TRIGONIIDÆ—
e *Trigonia scabra*, upper cretaceous.
T. orientalis.

LAMELLIBRANCHIATA—(*contd.*)

NUCULIDÆ—
Nucula crassicula.
ARCIDÆ—
Axinæa subplanata.
* *Macrodon japeticum.*
* *Trigonoarca brahminica.*
T. galdrina.
MYTILIDÆ—
Modiola radiatula.
M. annectans.
AVICULIDÆ—
Avicula (Meleagrina) nitida.
e * *Inoceramus cripsii*, upper cretaceous.
I. simplex.
Melina valida.
RADULIDÆ—
e *Radula (Ctenoides) tecta*, upper cretaceous.
R. (Acesta) obliquistriata.

PECTINIDÆ—
Pecten raduloides.
e *P. (Camptonectes) curvatus*, upper and middle cretaceous.
e *Amusium membranaceum*, upper and middle cretaceous.

SPONDYLIDÆ—
* *Plicatula instabilis.*

OSTRÆIDÆ—
e * *Exogyra ostracina*, upper cretaceous.
e * *Gryphæa vesicularis*, upper cretaceous.
e * *Ostrea (Alectryonia) pectinata*, upper cretaceous.
e * *O. (A.) ungulata*, upper cretaceous.
e *O. acutirostris*, upper cretaceous.

BRACHIOPODA.

e *Crania ignabergenis*, senonian; danian.
Rhynconella plicatiloides.
* *Terebratula subdepressa.*
e *T. biplicata*, cenomanian and turonian.
e *T. subrotunda*, turonian; senonian.

BRYOZOA (*Ciliopoda*).

Cellepora missilis.
Discopora obtecta.
* *Escharinella discors.*
* *Lunulites annulata.*
e *Proboscina radiolitorum*, turonian,
e *P. angustata*, cenomanian.
e *Entalophora lineata*, senonian.

ECHINODERMATA.

Hemiaster tuberosus.
H. indicus.
H. cristatus.
* *Epiaster nobilis.*
* *Stigmatopygus elatus.*
Cassidulus crassus.
Nucleolites pullatus.
e *Galerites* conf. *albogalerus* (*Echinoconus conicus*), senonian.
e *Marsupites milleri*, senonian; upper chalk.

ANTHOZOA.

Cyclolites fæcata.
* *C. filamentosa.*

VERMES.

e *Serpula filiformis*, cenomanian; turonian; senonian.
e *S.* conf. *gordialis*, upper cretaceous.

Uppermost Arialur beds of Ninnyur.—The fauna of the uppermost Arialúr beds found at Ninnyur and other places to the north-east of Arialúr, comprises very few species which are found in the lower portion of the group. Some of the fossils found most abundantly, such as *Nautilus danicus* and *Orbitoides faujasi*, are characteristic in Europe of the uppermost cretaceous deposits of Maestrict, Aix la Chapelle, and the Danish Island of Rügen (Danien of D'Orbigny). No other Cephalopod except *Nautilus danicus* occurs in the Ninnyur beds, whilst the characteristically mesozoic genera *Inoceramus*, *Radiolites*, *Trigonia*, *Trigonoarca*, and *Leptomaria*, which are abundantly represented in the lower portion of the Arialúr group, are entirely wanting in the uppermost fossiliferous zone, where the only important mesozoic genus is *Nerinæa*. On the other hand, however, no typically Tertiary forms make their appearance except carnivorous Gasteropoda, and these are not more numerous in proportion than in the lower zone, although some additional forms are represented.

The following list of the species collected near Ninnyur is probably imperfect. It is taken from the Palæontologia Indica, and some forms, the occurrence of which is especially mentioned by Mr. H. F. Blanford,[1] are omitted. Amongst these are two or three species of *Ovulum* (perhaps, as Dr. Stoliczka pointed out, *Cypreæ*[2] in a peculiar state of preservation), a *Trochus*, and a *Catopygus*. It is probable that some of the specimens collected were not sufficiently well preserved for specific identification, or that they have been overlooked. The distinctive marks are the same as before, with one addition, a dagger † being prefixed to the names of all species found also in the lower zone of the Arialúr group in the Trichinopoly area, or in one of the lower sub-divisions of the cretaceous series in Southern India.

CEPHALOPODA.

NAUTILIDÆ—

e * *Nautilus danicus*, uppermost cretaceous.

[1] Mem. G. S. I., IV, pp. 140, note, 141. That there is some confusion about the fossils from this locality is shewn by the circumstance that in the "Palæontologia Indica," Cretaceous Fauna, Vol. II, p. 221, and again p. 227, *Turritella elicita* and *T. ventricosa* are said to occur at Ninnyur with *Nerinæa blanfordiana*, whilst at p. 184, where *N. blanfordiana* is described, it is only said to be found in the Utatúr group, and no mention is made of the Ninnyur locality. At p. 221 several *Cypræidæ* and *Volutidæ* are mentioned as associated with *Turritella elicita* and *Nerinæa blanfordiana*, but not a single species of *Cypræidæ* is quoted from the locality, and only two species of *Volutidæ*, *viz.*, *Scapha gravida* and *Lyria formosa*.

[2] Pal. Ind., Cret. Faun., Vol. II, p. 47.

GASTEROPODA.

HELICIDÆ—
† *Helix* (*Angystoma*) *cretacea.*
H. (*A.*) *arrialoorensis.*

VOLUTIDÆ—
Scapha gravida.
* *Lyria formosa.*

BUCCINIDÆ—
Pseudoliva subcostata.

PURPURIDÆ—
* *Rapa corallina.*

CANCELLARIIDÆ—
† *Narona eximia?* also found in the Trichinopoly group, the identification of the single Ninnyur specimen somewhat doubtful.

PYRAMIDELLIDÆ—
† *Nerinæa blanfordiana;* also found in the Utatúr group.

TURRITELLIDÆ—
Turritella (*Torcula*) *asperata.*
T. elicita.
T. (*Zaria*) *ventricosa.*

SOLARIIDÆ—
Solarium arcotense.

RISSOIDÆ—
Keilostoma substriatum.

NATICIDÆ—
* *Ampullina sortita.*
e* *Euspira lirata,* turonian; senonian.
Mammilla edura.

ACTÆONIDÆ—
† *Actæon* (*Solidula*) *semen;* found also in the Trichinopoly group.

LAMELLIBRANCHIATA.

GASTROCHÆNIDÆ—
Rocellaria sp. indet.

TELLINIDÆ—
Tellina (*Tellinella*) *arcotensis.*

VENERIDÆ—
Cytherea (*Callista*) *laciniata,* Stol.
C. (*C.*) *discoidalis.*
Cyprimeria obesa.
Eriphyla forbesiana.

CARDIIDÆ—
Cardium (*Cerastoderma*) *pilatum.*

LUCINDIDÆ—
Corbis typica.
C. oblonga.
* *Lucina* (*Codakia*) *percrassa.*
† *L. fallax;* found also in the Utatúr group.
L. (*Cyclas*) *tæniolata.*

ASTARTIDÆ—
Cardita jacquinoti.

CRASSATELLIDÆ—
Crassatella zitteliana.

NUCULIDÆ—
* *Nucula indefinita;* found near Pondicherry also.

ARCIDÆ—
† *Axinæa altiuscula.*
Cucullæa æquata.
Barbatia decora.

RADULIDÆ—
Radula interplicosa.

PLACUNIDÆ—
Hemiplicatula detrita.

OSTRÆIDÆ—
e *Exogyra laciniata,* upper cretaceous.
e † *Gryphæa vesicularis,* upper cretaceous.

BRYOZOA.

Membranipora pedata.

ANTHOZOA.

Stylina parvula.
Holocœnia indica.
e† *Astrocœnia decaphylla.* Turonian.
Thamnastræa brevipes.

FORAMINIFERA.

e† *Orbitoides faujasi,* uppermost cretaceous.

Relations between faunas of different groups.—Besides the fossils characteristic of each group, there are a few species which are found throughout the whole series. Of these the most important are the following:—

Nautilus huxleyanus.
e *Ammonites planulatus,* cenomanian; gault.
e *Ampullina bulbiformis,* turonian; senonian.
Gyrodes pansus.
e *Solariella radiatula,* senonian.
e *Vola quinquecostata,* upper and middle cretaceous.

Ammonites menu, Forbes, is also supposed to be found in all three sub-divisions, although there is some doubt about the Utatúr beds, and a rare *Lucina, L.* (*Myrtea*) *arcotina,* has also been procured from all the groups. Some of these fossils, although found throughout the series, are especially characteristic of one sub-division, as in the cases of *Nautilus huxleyanus* and *Solariella radiatula.* A larger number of forms are common to two groups. The following table exhibits the number of each class of *Invertebrata* found in the different formations, and the proportion found also in Europe, or common to two or more groups. The *Vertebrata* are represented by 17 species of fishes and one Saurian, but the remains are of the most fragmentary description, consisting in most cases of single teeth, and it is not certain from which group some of the specimens were originally derived:—

Table shewing the distribution of invertebrate fossils in the cretaceous rocks of Southern India.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Total number of species found in Utatúr group.	Peculiar to Utatúr group in India.	Species included in column 2 found also in Europe.	Total number of species found in Trichinopoly group.	Peculiar to Trichinopoly group in India.	Species in column 5 found also in Europe.	Total number of species found in Arialúr group.	Peculiar to Arialúr group in India.	Species in column 8 found also in Europe.	Species common to Utatúr and Trichinopoly groups.	Species common to Utatúr and Arialúr groups.	Species common to Trichinopoly and Arialúr groups.	Species common to all three groups.	Total species in South Indian cretaceous series.	Total found also in Europe.
Cephalopoda	109	95	25	23	10	4	36	20	5	4	7	6	3	146	38
Gasteropoda	43	36	5	86	59	6	138	113	10	3	1	1	3	237	30
Lamellibranchiata	79	69	8	66	51	5	117	106	10	6	2	7	2	243	29
Brachiopoda	9	8	3	5	2	1	12	8	3	...	1	3	...	21	9
Bryozoa	...	...	...	...	...	...	23	23	4	...	...	...	...	23	4
Vermes	1	1	...	...	...	...	2	2	2	...	...	...	...	3	2
Echinodermata	10	10	4	...	...	...	26	26	4	...	...	...	...	42	8
Anthozoa	42	42	2	6	5	3	10	9	...	...	...	1	...	57	5
Spongiozoa	1	1	1	...	...	...	...	...	...	...	...	...	...	1	1
Foraminifera	...	...	...	...	...	...	1	1	1	...	...	...	...	1	1
TOTAL .	294	262	48	186	127	19	365	308	39	13	11	38	8	774	127

Adding the few Vertebrata to the numbers given above, we have a grand total of nearly 800 species of animals from the South Indian cretaceous deposits. Much time was devoted to the collection of the fossils, and their exhaustive examination by Dr. Stoliczka[1] has furnished the best evidence extant for the correlation of any Indian fossil fauna with that of European rocks of corresponding age. Of the whole Invertebrata, 16·36 per cent. consist of forms known to occur in cretaceous beds in Europe. Of these, the great majority are middle or upper cretaceous (cenomanian to senonian); but there are amongst the *Cephalopoda* several forms which in Europe have only been found in lower beds (neocomian and gault), whilst a few are representatives of European jurassic forms, and three species of *Ammonites* belong to a triassic section of the genus. The general facies of the cephalopodous fauna found in the lowest group, that of Utatúr, approximates to that of the European gault, but nearly all the species of the other classes of Mollusca found in the same beds belong to a higher horizon, cenomanian (upper greensand), or even higher.

Physical geography of South India in cretaceous times.—The whole of the cretaceous rocks of Southern India appear to have been formed in shallow water, and in the neighbourhood of a coast line; and it is possible that the relative elevations of the country have undergone but little change since cretaceous times.

Then, as now, there was higher ground to the westward, and the ancient coast line appears to have been approximately parallel to the present, although farther to the west. We have thus in the cretaceous formation a confirmation of the evidence already afforded by the lower mesozoic deposits, that the Indian Peninsula is a land area of great antiquity.

Connexion with cretaceous rocks in other parts of India.—As will be presently shewn, there is a great difference between the fauna of the cretaceous rocks in Southern India and that of the deposits of similar age on the Narbada; but, on the other hand, many of the fossils of the Trichinopoly area are found in the cretaceous rocks of the Khási hills, to the north-east of Bengal, between Assam and Sylhet.[2]

[1] In his account of the *Gasteropoda* and *Lamellibranchiata*, Dr. Stoliczka entered at great length into the question of the general classification of all the genera, recent and fossil, belonging to the families represented in the rocks of Southern India. In the case of the volume devoted to the *Lamellibranchiata* or *Pelecypoda* more especially, a complete list of all genera known, living or extinct, with the typical species in each case, was appended to the Introduction.

[2] These will be described in a separate part of this work. The Khási hills are about 1,200 miles distant from Pondicherry.

So many species are common to the Trichinopoly and Khási deposits, that it is probable that the two regions were part of the same marine area. The cretaceous rocks of the Khási hills are almost unquestionably identical with those extending throughout the hill ranges south of Assam; and the same strata are probably represented in Arakan.

Relations to cretaceous rocks of South Africa.—Before quitting the subject of the Trichinopoly cretaceous beds, it is necessary to notice the very remarkable resemblance between a portion of their fauna and the species found in certain strata in Southern Africa.[1] In the description of the Gondwána system, and again in the account of the upper jurassic beds of Cutch, the remarkable affinities between Indian fossil plants and animals, and the forms found in South African beds, were repeatedly noticed, and there is a similar connexion between the cretaceous formations in the two regions. In some deposits found resting upon Karoo beds on the coast of Natal, out of 35 species of *Mollusca* and *Echinodermata* collected and specifically identified, 22 are identical with forms found in the cretaceous beds of Southern India, the majority being Trichinopoly species. Amongst the South African fossils are *Ammonites gardeni* (Arialúr), *A. kayei* (Utatúr), *Anisoceras rugatum* (Utatúr), *Pugnellus uncatus* (Trichinopoly), *Fasciolaria rigida* (Trichinopoly), *Chemnitzia undosa* (Trichinopoly), *Euchrysalis gigantea* (Trichinopoly and Arialúr), *Solariella radiatula* (all three groups), *Avellana ampla* (Trichinopoly), *Turritella multistriata* (Trichinopoly and Arialúr), *Pecten* (*Vola*) *quinquecostatus* (all three), and *Cardium hillanum* (Trichinopoly) or some of the commonest and most characteristic fossils of the South Indian cretaceous deposits. There is also some slight indication of a representation of the different Indian zones.

The South African beds are clearly coast or shallow water deposits, like those of India, and the great similarity of forms certainly suggests continuity of coast line between the two regions, and thus supports the view that the land connexion between South Africa and India, already shewn to have probably existed in both the lower and upper Gondwána periods, and of which important indications are afforded by the marine jurassic beds, was continued into cretaceous times. It is very surprising to compare the middle cretaceous fauna of Southern India with that of the distant beds of Natal, and then with the widely differing forms found in beds of the same age in Central India and Southern Arabia. The latter will be noticed presently.

[1] Griesbach, Q. J. G. S., 1871, p. 60. Some of the fossils were described by Bailey, Q. J. G. S. 1855, p. 454.

Cretaceous fossils of Sripermatur near Madras.—Amongst the descriptions by Dr. Stoliczka of the cretaceous fossils from Southern India, the following species of *Lamellibranchiata* are included from Sripermatúr, 25 miles west-north-west of Madras, already mentioned as the typical locality for a group of the Upper Gondwána series:—

LUCINIDÆ—
Sphæriola, sp. indet.
UNGULINIDÆ—
Hippagus emilianus.
NUCULANIDÆ—
Yoldia obtusata ?
ARCIDÆ—
Trigonoarca galdrina.
AVICULIDÆ—
Pseudomonotis fallaciosa.
P. inops.
RADULIDÆ—
Limea oldhamiana.
PECTINIDÆ—
Pecten arcotensis.

Two of these, *Yoldia obtusata* and *Trigonoarca galdrina*, are also found in the Arialúr group of the Trichinopoly district, but the identification of the Sripermatúr species referred to the *Yoldia* is slightly open to doubt. *Trigonoarca galdrina* is, however, a well-marked form, and it belongs to a characteristically cretaceous genus.

The specimens were collected by the late Mr. Charles Oldham before the country was properly examined, and there appears some slight doubt as to the precise beds from which they were obtained. Some of the specimens were from Sripermatúr itself, others from Rajah's Choultry. The only cretaceous fossils found by Mr. Foote, who mapped the country in the Sripermatúr neighbourhood, occurred in water-worn blocks of grey or greenish-grey gritty sandstone resting loosely on the surface of jurassic beds near Sripermatúr.[1] The origin of these boulders could not be traced, and the fossils cannot now be found; amongst the forms obtained were four or five species of *Ammonites*, some *Belemnites*, &c.

Cretaceous beds of the Narbada valley or Bagh beds.—The marine cretaceous formations found in the western portion of the Narbada valley have been commonly known as "Bágh beds," from the town of Bágh, which is situated about 90 miles west by south of Indore, and 35 miles west-south-west of Dhar. The town is not on cretaceous rocks, though they are well developed in the neighbourhood. The occurrence of cretaceous fossils near Bágh was discovered by Colonel Keatinge[2] in 1856, but the existence of fossiliferous limestone in this part of the Narbada valley had been known for a long time, although the exact locality had not been ascertained. The circumstance that blocks of limestone, containing fragments of *Bryozoa* and other fossils, had been employed in building the houses of Mándu (Mándoo), a city now in

[1] See Mem. G. S. I., X, p. 61. [2] J. A. S. B., 1858, XXVII, p. 116.

ruins, about 20 miles south of Dhár, first attracted attention, and it was mainly owing to an ingenious and happy suggestion of Dr. Carter's[1] that attention was attracted to the neighbourhood of Bágh, where limestone had been observed in 1818 by Captain Dangerfield.

The cretaceous rocks of the lower Narbada valley[2] occur chiefly along the edge of the Deccan traps, and intervene between the latter and the metamorphic rocks. West of Bágh the outcrop of the cretaceous beds may be traced with a few interruptions to the neighbourhood of Baroda. East of Bágh, they only occur in places around the inliers of older rocks, and in this direction they appear to pass into the unfossiliferous Lameta group, which will be described in a subsequent page in connection with the Deccan traps.

Mineral characters and distribution.—As a general rule, the Bágh beds are composed of a calcareous rock above and of sandstone below, but the character of each portion of the formation varies. Commencing to the eastward, the first place where marine cretaceous beds are known to occur is in the neighbourhood of Barwai, on the Narbada, nearly due south of Indore. Here some conglomerates, more or less calcareous, and sandstones containing marine shells, represent the cretaceous formation, and in one place are seen to be distinctly unconformable to an outlier of Mahádeva conglomerate belonging to the upper Gondwána series.[3] From the neighbourhood of Barwai the whole Narbada valley is composed of trap for nearly 50 miles to the westward. Lower rocks reappear near Mándú, between which place and Bágh the cretaceous beds are found, forming a narrow fringe to the traps, around several inliers of Bijáwar and metamorphic rocks. The general descending section of the Bágh beds near Cherakhan, 22 miles east of Bágh, is the following:—

	Feet.
Coralline limestone	10 to 20
Argillaceous limestone, fossiliferous, about	10
Unfossiliferous nodular limestone	20
Sandstone and conglomerate	20

The so-called coralline limestone is the rock of which Mándú was built, and to which reference has already been made; it is yellow or red in colour (the former tint being doubtless due to some carbonate of iron, in the limestone exposed to the air, being converted into peroxide), and consists chiefly of small fragments of *Bryozoa*, shells, &c. The

[1] Jour. Bom. Br. R. A. S., V, p. 238.

[2] For a more complete description, see Mem. G. S. I., VI, pp. (207)-(219), (264), (294), (323), &c.

[3] For additional details, see Rec. G. S. I., VIII, p. 72.

freshly broken surface has a somewhat granular mottled appearance, and the fossils are not conspicuous; they weather out on exposure. In many places this bed is obliquely laminated. Beneath it, is an impure argillaceous limestone from which all the fossils of the Bágh beds hitherto procured in this neighbourhood have been obtained. They are chiefly Echinoderms, *Hemiaster* being the prevalent genus. These two bands of limestone are only found in the neighbourhood of Cherakhan, and neither has hitherto been found west of Bágh.

The nodular limestone and the sandstone are more extensively developed. At Bágh itself from 15 to 20 feet of the limestone rest upon 80 or 100 feet of sandstone. The limestone is nearly unfossiliferous, only here and there a fossil occurs in it, and the few specimens found are but rarely well preserved. The sandstones are fine or coarse, white and purple in colour, and frequently conglomeratic. Sometimes they are shaly or calcareous.

West of Bágh, the cretaceous rocks occupy a considerable area, their outcrop being nearly 15 miles broad, and their thickness, especially to the southward, must be much greater than at Bágh. Farther to the westward, they form a fringe of varying width along the northern edge of the trap, and they also appear in several inliers within the trap boundary. At Alli (Allee), 30 miles west-south-west of Bágh, a section is exposed exhibiting 150 to 200 feet of sandstone, on which rests conglomerate, capped by limestone, with a few corals, echinoderms, &c. The largest expanse of the cretaceous beds to the westward is on the edge of the alluvium of Guzerat, near the village of Talukwára, 35 miles south-east of Baroda. Here they cover a tract lying just north of the Narbada river, and about 15 miles long from north by east to south by west, by 6 or 7 miles broad. About 10 miles to the south-east, south of the Narbada, there is a large inlier, about 6 miles from north to south and 10 from east to west, entirely composed of cretaceous rocks, of which good sections are exposed in the Deva stream, a tributary of the Narbada. The base is not seen, but a thickness of at least 1,000 feet of cretaceous rocks is exposed, and here, as in the tract near Talukwára, the upper portion consists of dark-coloured shales, more or less calcareous, and not unfrequently containing oysters, whilst the lower portion is composed of coarse sandstones and conglomerates. The shales in the Deva inlier are 500 feet thick.

One peculiarity of the uppermost calcareous beds is the frequent occurrence in them of cherty or flinty masses. This character causes the beds closely to resemble the Lameta or infratrappean rocks, and it may in both cases be due to the same cause—infiltration of silica from the overlying trap.

Physical geology.—Throughout the area of the cretaceous rocks on the Western Narbada there is a constant tendency to increase in thickness to the southward. To the north, the Bágh beds are represented by a thin band frequently not more than 10 or 15 feet thick, of coarse sandstone and conglomerate. To the south, as just noticed in the Deva valley, these strata are at least 1,000 feet thick. It is true that a great part of this thickness consists of sandstone, and the suggestion has already been made[1] that this sandstone may belong to the Mahádeva series, but the two facts, that no unconformity has been detected between the calcareous shales, which are certainly cretaceous, and the underlying sandstone, and that both formations increase similarly in thickness to the southward, are strongly in favour of referring both to the same age.[2]

As a rule, the cretaceous rocks near Bágh are but little disturbed. More to the westward they have in general a low dip to the south, as have also the overlying traps. The cretaceous strata rest unconformably upon old metamorphic and Bijáwar beds, and the only instance in which they have been observed in connexion with older beds of later date than the transition series is that already mentioned near Barwai. The relations between the Bágh cretaceous rocks and the Deccan traps will be described when treating of the latter series.

Palæontology.—No large collections of fossils have been procured from the beds of Bágh, and of those obtained, many are ill preserved, and the majority have not as yet been determined. Some fragmentary *Ammonites* and *Belemnites* have been found, but the only common fossils besides oysters are Echinoderms, *Pecten (Vola* or *Janira) quadricostatus,*[3] and a few other bivalves; a *Rhynconella* is also found. The following fossils were determined by Prof. Martin Duncan[4] :—

LAMELLIBRANCHIATA—
Neithea alpina.[5]
Pecten (Vola) quadricostatus.

BRACHIOPODA—
Rhynconella depressa.

BRYOZOA—
Escharina, sp.
Eschara, sp.

VERMES—
Vincularia, sp.
Serpula plexus.

ECHINODERMATA—
Hemiaster cenomaniensis.
H. similis.
Echinobrissus similis.
E. subquadratus.

CORALLIA—
Thamnastræa decipiens.

[1] *Ante*, page 221.

[2] The Mahádeva beds, it should be remembered, are supposed to be of Jurassic age.

[3] This is said by Dr. Stoliczka to be probably identical with *Pecten (Vola) quinque-costatus*, Pal. Ind., Ser. VI, Cret. Faun., III, p. 438.

[4] Q. J. G. S., 1865, XXI, pp. 353 and 354.

[5] According to Dr. Stoliczka, Pal. Ind., Ser. VI, Cret. Faun., III. pp. 426, 438, *Neithea* is identical with *Vola* and *Janira*, and *N. alpina* but doubtfully distinct from *Vola (Pecten) quinque-costata*.

Some of the species have a wide range in time amongst the cretaceous rocks of Europe, but all occur in the upper greensand (cenomanian), many being characteristic forms, and the cretaceous rocks of the Narbada valley must in consequence closely correspond to the Utatúr group of Southern India. It is curious to note that, so far as is known, only one species, *Pecten* (*Vola*) *quinquecostatus*, is common to both, and even in this case the identification depends upon a question as to which palæontologists are not thoroughly agreed. The species moreover is one of wide range both in time and space. *Hemiaster similis* and *H. cenomaniensis* are remotely allied to *H. rana* (Arialúr) and *H. expansus* (Utatúr) of the Southern Indian cretaceous deposits, and *Thamnastræa decipiens* is replaced in the Utatúr beds by a closely allied form, *T. hieroglyphica*, Stol.

Relations to cretaceous fauna of Southern Arabia.—In strange contrast with the wide difference between the known fauna of the Bágh beds and that of the Southern Indian deposits is the similarity between the fossil remains of the Narbada valley and those found in two localities, Ras Fartak and Ras Sharwen on the south-east coast of Arabia.[1] The collections examined from both localities are small, and were obtained in each case during a short visit; but although the united Arabian collections only comprise 13 species and the Bágh 12, three of these, *viz.*, *Hemiaster similis*, *Vola quadricostata*, and *Neithea alpina*, are common to the two countries.

The cretaceous beds of the lower Narbada valley are about 750 miles distant from those of Southern India, and twice as far from the Arabian localities. The marked contrast between the fossil fauna in the one case, and the similarity in the other, tend to suggest the probability that a land barrier interposed in middle cretaceous times between Southern India with Assam and Arakan on the one side and the Western Narbada region with the south coast of Arabia on the other. We have thus another argument presented to us in favor of the Indian Peninsula being the portion of an ancient land area; and taking into consideration the marked connexion between the faunas of the South Indian and South African cretaceous deposits and the circumstance that both appear to be of littoral origin, it is probable that this land area extended to Africa.

[1] See Prof. Martin Duncan's paper in the Quart. Jour. Geol. Soc. already quoted; 1865, pp. 352 to 354, &c. The Arabian localities were originally described and the fossils collected by Dr. Carter (Jour. Bom. Br. R. A. S., Vol. IV, p. 71, and geological papers on Western India, pp. 603, &c.).

At the same time the coarseness of the Narbada cretaceous rocks shews that they must have been deposited in the neighbourhood of a coast, and their rapid increase in thickness to the southward renders it likely that land existed to the north. On the whole, it is most probable that they were formed in a bay or inlet, open to the westward and closed to the eastward, in which direction beds of similar character, but apparently of fresh water origin, are found occupying the same position at the base of the Deccan traps.

CHAPTER XIII.

PENINSULAR AREA.

DECCAN TRAP SERIES.

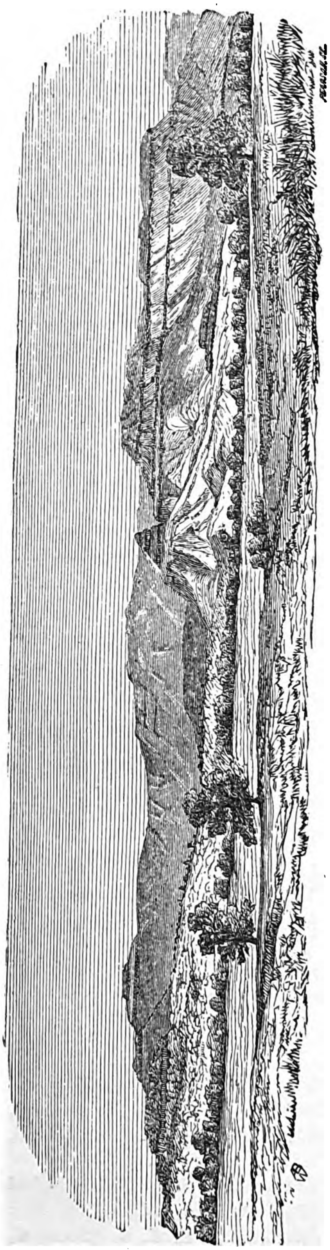
Area occupied and original limits — Name of series — Scenery and vegetation of trap area — Petrology — Volcanic ash — Minerals, original or of secondary origin — Horizontality of traps — Thickness of lava flows — Sedimentary beds associated with traps and classification of series — Whole thickness of series — Lameta group — Relations to older formations — Distribution — Fossils — Intertrappean beds of Nágpúr, the Narbada valley, &c. — Fossils of the lower intertrappeans — Marine beds, associated with trap near Rájámahendri — Infratrappean — Intertrappean beds of Rájámahendri — Fossils — Upper intertrappean beds of Bombay — Fossils — Origin of the Deccan traps subaërial — Relations of Deccan traps to underlying rocks — Subaërial origin of traps proved by occurrence of fresh-water beds — Lower traps not poured out in a great lake — Horizontal traps difficult to explain — Volcanic foci — Geological age of the Deccan traps — Probable conditions prevailing during Deccan trap epoch.

Area occupied and original limits.—In contradistinction to the formations described in the last few chapters, the great volcanic series[1] of India is one of the most prominent and widely spread of all the rock systems found in the Peninsula. In superficial area the Deccan traps are only exceeded within the limits of peninsular India south of the Indo-Gangetic plain by the metamorphic series, and although the traps are far inferior in thickness to the Vindhyan and Gondwána formations, their remarkable horizontality throughout a great part of the region covered by them enables them to conceal all older rocks. Some faint idea of the extensive area occupied by this formation may be gained from the fact that the railway from Bombay to Nágpúr, 519 miles long, never leaves the volcanic rocks until it is close to the Nágpúr station, and that the traps extend without a break from the sea-coast

[1] This series has been described more or less fully by numerous geological writers, especially Sykes (Geol. Trans., Ser. 2, Vol. IV, p. 409), Malcolmson (*id.*, Vol. V., p. 537), Carter (Jour. Bombay Br. R. A. S., Vol. V, p. 255, &c.), and Hislop (Q. J. G. S., 1855, p. 356; 1860, p. 154).

For further details and references, the following parts of the "Memoirs of the Geological Survey of India" may be consulted:—Vol. II, p. 217; VI, pp. (137), (219), &c.; IX, pp. (58), (318); X, p. (178); and XII, p. (171); also Records, G. S. I., I, p. 60; V, p. 115.

at Bombay (longitude 72° 51′ east to Amarkantak at the head of the Narbada (longitude about 82° east), and from near Belgaum (latitude 15° 35′ north) to north of Goona (latitude 25° north). Even this extent, great as it is, by no means represents the whole area originally occupied by the formation, for outliers are found east of Amarkantak as far as Jumera Pat in Sirgúja (longitude 84° east), and to the south-east a small outcrop occurs close to Rájámahendri, whilst to the westward the series is well developed in Kattywar (Kathiawad) and Cutch (Kachh), and it has even been found represented, though by two very thin bands, west of Kotri in Sind (latitude 68°). To the north and south the evidence of the original limit is imperfect; we have, however, proof of the existence of this volcanic formation throughout nearly ten degrees of latitude and sixteen of longitude, whilst the area covered in the Peninsula of India can be little less than 200,000 square miles. It is probable that the limits mentioned very nearly correspond to the original boundaries of the volcanic rocks, because the high level laterite, which rests conformably upon the uppermost traps of the Deccan, is found to the southward, eastward and northward, overlying rocks older than the volcanic series, and if, as will be shewn to be probable in a later chapter, this laterite was formed at a date immediately subsequent to the cessation of the igneous outbursts, it may be inferred that the lava flows never extended to the localities (such as Gwalior, Rewah, Bastar, &c.) in which the laterite is found resting immediately upon Vindhyan, transition, or metamorphic rocks.



Málwa Ghats from the Narbada valley, near Mahesar.

Name of series.—In adopting the name of "Deccan[1] trap" for this great volcanic formation, the Geological Survey has been guided partly by old usage, partly by the circumstance that the term "trap" was originally applied to similar horizontally stratified lava flows. Some geologists have condemned the term on account of the loose manner in which it has been used for a great variety of igneous rocks, but it is difficult to replace it, and in the present case, at all events, it is employed in a well defined sense.

Scenery and vegetation of trap area.—In consequence of its geological structure, the volcanic region of Central and Western India is distinguished by marked peculiarities of scenery, and the characters of the surface are widely different from those found in other parts of the Indian Peninsula. Great undulating plains, divided from each other by flat-topped ranges of hills, occupy the greater portion of the country; and the hill-sides are marked by conspicuous terraces, which may often be traced for great distances, and are due to the outcrop of the harder basaltic strata, or of those beds which resist best the disintegrating influences of exposure. In some parts of the area great scarps are found, some of those in the Sahyádri range being 4,000 feet in height, all conspicuously banded with horizontal terraces. Examples of the ordinary scenery of the trap region are shewn in the accompanying woodcuts.

Hill composed of Deccan trap, near Harngaon, north of Nimawar, Narbada valley.

The vegetation of the trap area differs no less conspicuously from that which is found on other formations; the distinction in the dry

[1] It is scarcely necessary to state that the Deccan comprises that part of the Indian Peninsula which is south (*dakhin*) of the Vindhyan range.

season being so marked that, especially when taken in connexion with the form of the surface, it enables hills and ranges of trap to be distinguished at a distance from those composed of other rocks. The peculiarity consists in the prevalence of long grass and the paucity of large trees,[1] and in the circumstance that almost all bushes and trees, except in the damp districts near the sea, are deciduous. The result is, that the whole country, except where it is cultivated, presents during the cold season, from November till March, a uniform straw-coloured surface, with but few spots of green to break the monotony; whilst from March, when the grass is burnt, until the commencement of the rains, in June, the black soil, black rocks, and blackened tree stems present a most remarkable aspect of desolation. During the rainy season, however, the country is covered with verdure, and in many parts it is very beautiful, the contrast afforded by the black rocks only serving to bring into relief the bright green tints of the foliage.

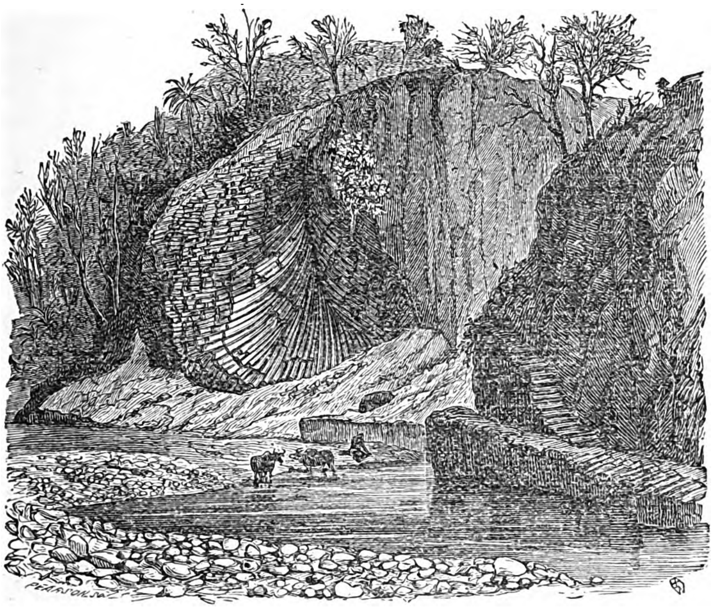
Petrology.—Throughout the trap area the prevailing rock is some form of dolerite or basalt,[2] but there is a large amount of variation in the characters presented by different beds. Some are excessively compact, hard, and homogeneous, the crystalline structure being so minute as to be detected with difficulty (anamesite); others are coarsely crystalline, and these frequently contain olivine in considerable quantities; and one variety is porphyritic, and contains large tabular crystals of glassy felspar, white or green in colour. Many of the basalts again are soft and earthy, evidently in most cases, and probably in all, from partial decomposition. The most striking peculiarity is, perhaps, the great prevalence of amygdaloid, in which the nodules, chiefly containing zeolite or agate, sometimes form the principal part of the rock. These nodules are very often coated with glauconite (green earth), and the prevalence of this mineral is highly characteristic. Almost throughout their range, the Deccan traps may be recognized by the occurrence of the amygdaloidal basalts with green earth, or of the porphyry with crystals of glassy felspar.

Exfoliating concretionary structure is common in the softer forms of basalt, which have undergone some amount of decomposition, but it is

[1] The want of large trees is partly due to the wanton destruction to which the forests of India have been exposed for ages through reckless cutting, to equally reckless clearing for temporary cultivation of a rude kind, and, perhaps, more than all, to the practice of annually burning the grass at the commencement of the hot season.

[2] The meaning in which these names of rocks are used will be explained in the glossary at the end of this work. So far as is practicable, the terms are employed in the sense in which they are accepted by English geologists generally. A well-known German school of which Professor Zirkel and Baron von Richthofen are distinguished exponents, and which holds views, not admitted by English geologists, as to the limitation of different kinds of volcanic rocks to particular geological horizons, adopts the same terms with a somewhat different acceptation.

never seen in the hard compact beds. Frequently the hard unaltered spheroidal cores of concentric nodules are to be found scattered over the surface of the bed, from which they have weathered out, and they may easily be mistaken for rolled fragments. Columnar structure is less common, though it is occasionally seen, a fine example being shewn in the following woodcut. In some cases this structure has been observed in



Radiating basaltic columns; in a dyke near Gújri, north-west of Mahesar, Narbada valley.

the compact basaltic flows; it is frequently seen in the lowest flow, a very thick one, in the Narbada valley, west of Hoshangabád, and in one of the lower flows in Málwa, but the appearance is often confined to intrusive dykes, as in the example illustrated. Trachytic rocks are extremely rare, and have hitherto only been found in intrusive masses.

Volcanic ash.—Beds of volcanic ash are common, so common indeed in places as to form a very considerable proportion of the strata, and they appear to be much more prevalent towards the upper part of the series.[1] They often differ but little in appearance from the basaltic lavas with which they are interstratified, but on close examination

[1] This may be due to the circumstance that the upper part of the series is chiefly preserved in localities which were near the old volcanic foci. Ashes are found interstratified with the lower beds on the Narbada, west of Baroda, where remains of ancient volcanic cores also occur.

their brecciated structure can always be readily detected, and the blocks of scoriæ which they contain generally weather out on exposed surfaces and remain in relief, precisely as on old volcanic cones. Magnificent examples are to be seen on most of the higher portions of the Sahyádri or Western Ghát range, and on the high peaks, formerly used as hill forts, around Poona; well-marked instances occur also in Bombay and Salsette.[1] Very frequently a thin bed of ash intervenes between two basaltic flows. Occasionally pumice is found in the ash beds, the interstices, however, being all filled up by the same process as that by which vesicular lava has been converted into amygdaloid. Here and there, throughout the traps, beds of red bole occur; they are usually only a foot or two thick, but occasionally more. Sometimes the bole contains scoriæ; and in this case it frequently covers the upper surface of a basaltic flow, into which it appears to pass. In some instances the bole is so uniformly stratified that it has the appearance of having been deposited from water.[2]

In a few instances bands of very homogeneous structure and of a pale lilac colour, formed of an apparently argillaceous rock, resembling bole in texture, and so perfectly laminated as to exactly simulate shale, have been found interstratified with the basalts. This is especially the case at a large hill called Powagarh, 2,000 feet high, near Baroda, and similar beds are said to occur in Kattywar; they have also been noticed east of Surat. The occasional occurrence of glassy felspar crystals in these beds and the circumstance that some of the harder basalts at times weather on their exposed edges into a somewhat similar soft lilac rock, render it possible that these shaly strata result from the alteration of trap. At the same time it is far from improbable that some of them may be consolidated volcanic mud, composed of fine lapilli washed down and deposited by water.

Minerals, original or of secondary origin.—Amongst the original mineral constituents of the doleritic lavas, but few are sufficiently

[1] Amongst the best examples are the rock in which the Kanheri caves of Salsette are cut, some beds on the Kamatki ghât between Poona and Mahábleshwar, and a conspicuous bed at the lower gateway of the fortress of Sinhgarh near Poona. Ash-breccias also occur in Bombay Island at Flag-staff hill and Rai hill, Parel, and in the neighbourhood of Sion Fort. It must not be supposed from these examples that the rock is rare. It is found almost throughout the trap country, but it is much less common towards the base of the traps.

[2] Sir C. Lyell has shewn that bands of red clay interstratified with the lavas of Etna have been formed from the crust of the lower lava flow decomposed into clay and then baked and reddened by the heat of the overlying flow, or where "volcanic sand has been showered down from above and washed over the older lavas by torrents and floods," Phil. Trans., 1858, p. 711. Similar beds appear to be characteristic of subaërial lava flows; Judd, Q. J. G. S., 1874, XXX, p. 227. See also p. 365.

distinct for recognition; no crystallised pyroxene has been observed except locally in some of the ash beds, and the only felspar which occurs in distinct crystals appears to be the form of orthoclase (glassy felspar) which is found in the porphyritic rock already mentioned. Olivine and magnetite are common, the former occurring as translucent yellowish grains, the latter in minute crystals, too small, as a rule, to be recognised by the naked eye, but easily detected, if abundant, by the effect of the rock upon the magnetic needle. Magnetic iron sand derived from the traps is frequently found in the streams which traverse the rocks. With the tabular felspar crystals small scales of red mica are found.

Secondary minerals of various kinds, which have been formed since the consolidation of the volcanic strata, are found in the greatest abundance in some of the flows, especially in the amygdaloidal, and in some of the more earthy and decomposed traps. These minerals not only form the nodules of the amygdaloid, but they are found lining cracks and hollows, the finest crystals being always in geodes or cavities, some of which are as much as two or three feet across, and even larger hollows lined with crystals are said to have been found. The commonest minerals are quartz, either crystaline or in the form of agate, bloodstone, jasper, &c. and *Stilbite,* next in abundance are *Apophyllite, Heulandite, Scolecite* (*Poonahlite*), *Laumonite* and *Calcite : Thomsonite, Epistilbite, Prehnite* and *Chabasite* also occur, but they are rare.[1] The great prevalence of *Glauconite* or green earth has already been noticed.

The crystalline quartz is occasionally, though rarely, amethystine ; it but seldom occurs in crystals which exceed an inch in diameter, and the larger crystals are not often transparent. The form known as trihedral quartz, in which the terminal pyramid of each quartz crystal consists of three planes instead of six, or in which three planes are very much more developed than the other three, is of common occurrence. The agates occur chiefly in geodes or nodules, large and small; many are finely banded, and, after being coloured by heating, are cut into ornaments.[2] Jasper and heliotrope or bloodstone occur chiefly in flat plates which appear to have been formed in cracks, and agate is sometimes met with of apparently similar origin. *Stilbite* is very common, though less so than quartz; one magnificent variety consists of large orange or salmon

[1] Two other mineral species besides poonahlite have been described from the Deccan traps. One of these is *Hislopite* (Haughton: Phil. Mag., 1859, Vol. XVII, p. 16) which appears to be calcite coloured by glauconite (green earth) and the other *Syhedrite* (Shepard; Am. Jour. Sci., July 1865, Vol. XL, p. 110) is stilbite coloured in the same manner.

[2] Most of the stones cut for ornaments are either procured from rivers or from the tertiary graavls derived from the denudation of the traps.

coloured crystals, often 2 or 3 inches in length, usually compound or in sheaf-like aggregations, but occasionally in large flat prisms terminated by a four-sided pyramid. *Apophyllite* is the finest of all the Deccan trap minerals. It generally occurs in four-sided prisms with terminal planes, a form which closely resembles the cubical crystals of the isometric system; the double pyramid, with replacements of the secondary prismatic faces and terminal planes, so characteristic of this mineral in other localities, being chiefly typical of small crystals in the Deccan traps. The colour of the Deccan apophyllite is usually white, more rarely pink or green; some crystals are perfectly transparent, and one of the most magnificent associations of minerals to be found anywhere is seen when, as occasionally happens, perfectly clear vitreous crystals of apophyllite, of large size, are inserted on a mass of orange stilbite. Some apophyllite crystals are as much as 3 and 4 inches across. The other minerals are less deserving of notice, but very beautiful long acicular crystals of scolecite with exquisitely formed pyramidal terminations are of occasional occurrence, and fine crystals of white heulandite are not unfrequent. The glauconite is usually amorphous, but occasionally forms an aggregate of crystalline scales, and a massive mineral which, if not green earth, is closely akin both in appearance and composition, occasionally occupies small cavities completely.

Horizontality of traps.—One of the most remarkable characters of the Deccan traps is their persistent flatness or near approach to horizontality throughout the greater portion of their area. This is conspicuous throughout the Sahyádri range, over the whole of the Bombay Deccan, from Khandesh to Belgaum and Sholapúr, throughout Southern Berar and the north-western portion of the Hyderabád territory, in many parts of the Sátpura range between the Narbada and Tapti, and on the Málwa plateau north of the Narbada. Where exceptions occur, as in the Western Sátpúra and Rájpipla hills, and along the coast near Bombay, the disturbance is shewn to be of later date from its affecting contemporaneous or newer beds of sedimentary origin. The only departure from absolute horizontality to be seen in the lava flows of the Deccan is frequently no more than may be due to the lenticular form of the beds, but usually there is a very low dip discernible, seldom exceeding 1°, and fairly constant over large areas. This circumstance tends to shew that even this small amount of inclination may be due to disturbance, because if the dips represented the original angle at which the lava flows were consolidated, they would be found to radiate from the original volcanic vents. Nothing of the kind has, however, been traced.

Thickness of lava flows.—The separate lava flows are, as a rule, of no great thickness. The average in the two sections of the Bor and Thul Gháts, measured on the railway lines, is apparently 64 and 87 feet respectively, but really less, because the distinction between the flows can in most cases only be recognised by lithological characters; and where, as must frequently be the case, two or more beds of similar appearance and composition occur together, they must often be confounded and measured as one. Many of the more amygdaloidal beds appear to be made up of several smaller flows from 6 to 10 feet thick, distinguished by being highly amygdaloidal above, less so in the middle, and traversed towards the base by long cylindrical, vertical pipes filled with zeolite.[1] But even supposing that these apparent distinctions are accidental, some well-marked crystalline flows in each section do not exceed 15 feet in thickness.

Associated sedimentary beds and classification of series.—Hitherto only the igneous portion of the Deccan series has been described, but volcanic rocks, although they form the great mass of the formation, do not compose it exclusively; for sedimentary bands, frequently fossiliferous, have been found in several places interstratified with the lava flows, and have become widely known and described as *intertrappean beds*. At the base of the whole series also there is found, in many places, a small group of limestones, sandstones and clays, known as the *Lameta group*, from its occurrence at Lameta Ghát, on the Narbada, near Jabalpur. Formerly this Lameta group was supposed to be an eastern representative of the Mahádeva formation (Gondwána), but further examination has shewn that the Mahádevas are much more ancient, and that the Lameta beds are so closely associated with the lowest trap that they must be considered as part of the same series. It has also been determined that intertrappean beds occur in two distinct portions of the Deccan series; first, close to the base, throughout the greater portion of the enormously extensive circuit of the volcanic area; and, secondly, in the highest portion of the traps, only known to occur close to the coast in Bombay Island and the immediate

[1] Bearing in mind that amygdaloidal basalt must have been originally vesicular lava, and that what are now nodules of quartz or zeolite were originally air or steam bubbles, it is easy to understand that the upper portion of a lava flow must have been more vesicular originally than the lower portion, and hence that a prevalence of amygdaloidal structure would be characteristic of the upper part of a flow. The vertical tubes must also have been originally filled with air or vapour, perhaps expelled from the underlying stratum by the heated mass flowing over it after it had been cooled and consolidated.

neighbourhood.[1] A rough classification of the whole series is presented in the following section :—

	Approximate[2] thickness in feet.
1. Upper traps, with numerous beds of volcanic ash and the intertrappean sedimentary deposits of Bombay . .	1,500
2. Middle traps, ash beds numerous above, but less frequent towards the base, no sedimentary beds known . .	4,000
3. Lower traps, with intertrappeans of Nágpur, Narbada valley, &c., volcanic ash of rare occurrence or wanting .	500
4. Lameta or infratrappean group	20 to 100

Whole thickness of series.—The whole thickness, as will be shewn presently, is probably considerably greater than 6,000 feet in the neighbourhood of Bombay, but the rocks gradually thin out in other directions. At Bombay the upper limit of the series is not seen. It is highly probable that near Surat and Baroda the trap may have been even thicker than near Bombay; but, as will be shewn hereafter, the upper portions have been greatly denuded, and it is extremely difficult here, as in most other places, to estimate the thickness with any accuracy. In Kachh (Cutch) the traps are about 2,500 feet thick, whilst in Sind they have dwindled down to two bands at different horizons, each less than 100 feet thick. Throughout the greater portion of their area, no higher beds except laterite or post-tertiary deposits are found resting upon them, and it is impossible to form any accurate estimate of their original development. In the extreme south of the volcanic area, near Belgaum, their thickness has been estimated by Mr. Foote to be 2,000 to 2,500 feet; on the plateau of Amarkantak, at the eastern extremity of their main area, they are about 500 feet thick, but farther east in the outlier on Main Pat in Sirgúja, not more than 300 to 400, whilst to the south-east near Rájámahendri they are represented by a thin outlier, in which from 100 to 200 feet of basalt may be exposed.

Lameta group.—Before proceeding further it will be necessary to give a fuller description of the sedimentary formations, and in accordance with the system adopted throughout this work, the Lameta group as the lowest will first receive attention.[3] The origin of the name has already been mentioned, and it has been stated that the group consists

[1] The reasons for considering the Bombay traps higher in the series than the others will be explained subsequently, when the intertrappean beds are described.

[2] The thickness given is little more than a guess, except in the case of the lower traps and Lametas. The other figures are minimum estimates of the vertical extent of the series where fairly developed.

[3] For further information, see Hislop: Q. J. G. S., 1860, p. 154; also Mem. G. S. I., II, p. 196; VI, p. (216); IX, p. (315); XIII, p. 87; and Rec., G. S. I., V, pp. 88, 115.

of limestones, sandstones and clays. The limestones are the most characteristic and persistent beds; they frequently occur alone, and they form the upper portion of the group, when other beds are associated with them. Occasionally the limestone is pure, but it is commonly full of sand and small pebbles, so as to form a calcareous grit rather than a limestone, and it abounds as a rule in masses, sometimes irregular, sometimes more or less lenticular in form, of segregated chert. Some of the small pebbles frequently consist of red jasper, the occurrence of which is very characteristic. This gritty limestone with its included chert nodules is found over a very extensive tract of country in the Central Provinces, and appears to be rarely absent throughout any large area in which the base of the traps is exposed. It is precisely similar in mineral character to the uppermost band of the Bágh beds, and the resemblance between the two, together with their position at the base of the traps, renders it probable that both may be of the same age. The occurrence of the chert nodules may be due in both cases to infiltration from the overlying traps, or to deposition from hot springs at the commencement of the volcanic epoch,[1] but the similarity of mineral character exists independently of the association of silica.

The bed which, after the limestone, is most commonly found in the Lameta group, is a rather fine porous earthy sandstone, usually of a greenish colour. The clays are red or green, and are very frequently sandy or marly; sometimes they contain nodular carbonate of lime. They are of local occurrence and appear but rarely to extend over any considerable area. All these beds pass into each other; the limestone is not unfrequently merely the sandstone cemented by carbonate of lime, the marls are an argillaceous form of the limestone, and except where the characteristic gritty limestone is the sole representative of the formation, there is, as a rule, a frequent change of character in the beds, both horizontally and vertically. This is usually the case where the thickness exceeds 20 or 30 feet; where the group is represented by a thin band, either the gritty limestone or the earthy greenish sandstone is commonly found alone.

Relations to older formations.—The Lameta group is quite unconformable to all the various older formations upon which it rests, from the metamorphics to the Jabalpur group. As a rule the lowest flows of trap are conformable to the infratrappean beds, but in some instances distinct unconformity has been detected, especially in one case

[1] See Judd: Geol. Mag., Dec. II, Vol. III, p. 343. In several volcanic areas in the neighbourhood of the Alps it is shewn that the volcanic eruptions were preceded by the appearance of springs containing, amongst other substances, silica in solution.

near Jabalpur[1] (Jubbulpore), and it is highly probable that closer examination would shew that such cases are common, and that in many localities where Lametas are wanting, their absence is due to denudation in pre-trappean times. At the same time the denudation appears to have been local, not general, patches occurring here and there, whilst, in the intervals between them, the trap rests upon a formation older than Lameta, but at such an elevation as to shew that the absence of the infratrappean bed is not due to the ground having been above the water in which the Lametas were deposited. It is impossible that the Lametas can ever have been co-extensive with the base of the trap, because the surface on which the latter rests is extremely uneven, and many portions of it must have been above the level at which the infratrappean beds were deposited. To this subject it will be necessary to recur, however, when discussing the relations of the trap series as a whole to the older formations.

Distribution.—It is unnecessary to give a list of localities at which the Lameta group has been observed. It is principally developed in the Central Provinces, around Nágpúr, Jabalpur, &c. It has not been found in the Southern Máhratta country, but elsewhere along the boundary of the volcanic area from the Godávari valley to Bhopal and Indore, it is rarely absent over any considerable area. As a rule, owing to its small vertical development, it only covers small portions of the surface, and it usually forms a narrow fringe to the trap country. In the Western Narbada valley it is replaced by the Bágh group, which, as already shown, it closely resembles in mineral character and stratigraphical relations, and of which it is not improbably a fresh water representative.

Fossils of Lameta group.—The Lameta group is, as a rule, singularly unfossiliferous, the principal fossils which have been found in it consisting of some bones of a large dinosaurian reptile, *Titanosaurus Indicus*,[2] allied to *Pelorosaurus* of the Wealden and *Cetiosaurus* of the Bath oolite. These fossils occur near Jabalpur, and similar bones, together with coprolites and some chelonian remains, are found at Phizdúra (Pisdura) about 8 miles north of Warora in the Chanda district.[3] In the last-named locality some of the characteristic fresh-water mollusca of the intertrappean beds, such as *Physa Prinsepii*, are associated with the bones, and in one or two other localities the same shells have also been found in beds at the base of the trap; for instance, a *Paludina*, apparently identical with *P. Deccanensis*, an intertrappean fossil, was found by

[1] Rec. G. S. I., V, p. 115.
[2] Lydekker: Rec. G S. I., X., p. 38.
[3] Q. J. G. S., 1860, p. 163; Mem. G. S. I., XIII, p. 88.

Mr. Hislop at Nágpúr,[1] *Melania* and *Corbicula* have been met with in infra-trappean beds near Ellichpur in Berar,[2] and *Physa Prinsepii* in a similar position at Todihal, 15 miles north-north-east of Kaladghi in the Southern Máhratta country.[3] But it is by no means clear in those localities, in which fresh-water shells are found in beds beneath the trap, with the exception of Nágpúr, that an intertrappean bed has not overlapped the edge of the underlying lava flow, so as to rest upon an older rock, which may be either Lameta or any other more ancient formation, and in the particular case of Phizdúra, where all the fossils are found scattered on the surface of a field consisting of red Lameta clay, there is always a possibility that *Physa Prinsepii* and similar fossils may come from some small unnoticed intertrappean band, concealed beneath the deep surface soil. At the same time it is by no means improbable that the *Physa* and other shells are really derived at Phizdúra from the Lameta beds, and that this group consequently is not much older than the volcanic beds which overlie it.

The only other noteworthy occurrence of fossils in the Lameta group is that of some fish remains at Dongargaon (Dongargaum) 6 miles east by south, and Dhamni, 9 miles east by north of Warora.[4] The species have not been described, but one of the fish found was considered by Sir P. Egerton allied to the *Sphyrænodus* (a cycloid acanthopterygian) of the London clay.

Intertrappean beds of Nagpur: the Narbada valley, &c.— Leaving the question of the mode of origin of the Lameta group to be discussed hereafter, and deferring for the moment the description of some beds with marine fossils found at the base of the traps near Rájámahendri, the next group which requires notice is that comprising the fresh-water beds interstratified with the lower traps in many parts of India, and especially in parts of the Central Provinces, Northern Hyderabád, Berar and the states north of the Narbada valley. Throughout these tracts of country and beyond them, almost throughout the great trap area, there are found here and there, near the base of the volcanic formations, and in no case, so far as has hitherto been recorded, at a greater height than from 300 to 500 feet above the base, thin bands of chert, limestone, shale or clay, often abounding in fossils of fresh-water or terrestrial origin.

Perhaps the most common form of the intertrappean bands, or that which is most conspicuous, is a compact blackish cherty rock, a kind of Lydian stone. It is clear that this rock has been originally a silt, and has been hardened, either by the outpouring of igneous rock over it

[1] Q. J. G. S., 1860, p. 167.
[2] Mem. G. S. I., VI, p. (283).
[3] *ib.*, Vol. XII, p. 193.
[4] Q. J. G. S., 1860, p. 162

or by chemical infiltration, the former being the more probable, because it very frequently happens that the upper portion of the bed only is cherty, the lower portion being a soft earthy shale. Other forms of intertrappean bands are a dark or pale grey limestone, often earthy and impure, but rarely gritty, like the characteristic Lameta bed. Not unfrequently the sedimentary bed is composed of volcanic detritus, whether removed by denudation from solid basalt, or consisting merely of the loose products of eruptions, such as lapilli, it is difficult to say. Red and green clays or bole are also found often associated with other intertrappean rocks.

As a rule, the sedimentary beds interstratified with the lava flows are distinguished from those underlying the whole volcanic series by the absence of pebbles and sand, but occasionally, though rarely, sandy and even pebbly beds are found at some distance above the base of the trap. In the Southern Máhratta country most of the intertrappean beds are sandstones and conglomerates. One peculiar detrital form of intertrappean accumulation has hitherto only been described from the country north of the Narbada and south of Chota Udepúr (about 50 miles east of Baroda) on the banks of the Karo, a tributary of the Hiran river.[1] The lower beds of the trap series here consist of conglomerates, sandstones, and sandy grits, sometimes resting on a stratum of basalt, but occasionally on the Bágh cretaceous beds, which underlie the volcanic formations. Occasionally the sandstone or conglomerate appears to be chiefly composed of detritus derived from the metamorphic rocks, but volcanic fragments, usually in the form of rolled pebbles of basalt, can always be found by search, and in many parts the bed becomes a mass of rolled volcanic fragments, often mixed with unrolled scoriæ. At times indeed the rock is a conglomeratic ash, in which rolled fragments of metamorphic rocks and of basalt occur together. Hornblend and pyroxene crystals have been found in these conglomeratic ashy beds, which are in some places as much as 200 feet thick. In some instances the conglomerates appear to have accumulated in hollows, like river beds; but in any case the abundance of rolled pebbles and boulders of trap is important as a proof that denudation took place in the interval between successive lava flows.

With the exception of the detrital accumulations which have just been mentioned, the intertrappean bands rarely exceed a few feet, from 3 to about 20, in thickness, and they frequently do not exceed 6 inches. In many places two or more sedimentary beds occur at different levels in the same section, and the different bands are in some cases dissimilar in mineral character. Thus, at Mekalgandi[2] Ghât in the Sichel hills, south

[1] Mem. G. S. I., VI, p. (327).

[2] Mucklegundy pass of Malcolmson.

of the Pen Ganga river, on the old road from Nágpúr to Hyderabád, a locality famous as being one of the first at which the intertrappean fossils were detected by Malcolmson, the following beds are observed in section :—

1. Trap.
2. Cherty bed containing *Unio*, *Cypris*, &c.
3. Trap.
4. Limestone containing *Cypris* and fragments of small mollusca.
5. Trap.
6. Calcareous grit, containing broken shells (Lameta).
7. Metamorphic rocks.

A single intertrappean bed can but rarely be traced for more than 3 or 4 miles without interruption; it then usually dies out; at the same time it is rare to go over any large tract near the base of the traps without finding some sedimentary bands interstratified, and occasionally one is found to be much more extensive than usual. Thus, an instance is recorded by Mr. J. G. Medlicott[1] in Sohágpur, east of Jabalpur, in which an intertrappean bed was traced for nearly 25 miles.

It would take up too much space to enumerate all the localities at which the lower sedimentary intertrappean beds have been observed. They have been noticed in several places in the Southern Máhratta country; they are commonly found near the base of the trap flows almost throughout the great and irregular line of boundary extending from the Godávari to Rajpútána, and they occur even in small outliers, for instance at Main Pat in Sirguja; they have been detected by Mr. Rogers[2] to the westward at Dohad in the Rewá Kantá, about 75 miles north-east of Baroda, and still farther west in Kachh[3] by Mr. Fedden of the Geological Survey.

Fossils of the lower intertrappeans.—The abundance of fresh water and terrestrial animals and plants in the intertrappean beds has been the principal reason for the comparatively large amount of notice which these thin bands of rock have attracted. The mollusca are very abundant and are occasionally exquisitely preserved in the cherty layers; the commonest species are forms of *Physa* and *Lymnea*, whilst *Unio*, although abundant locally, is of comparatively rare occurrence. *Paludina*, *Valvata* and *Melania* are far from uncommon. Land shells are

[1] Mem. G. S. I., II, p. 201.
[2] Q. J. G. S., 1870, p. 122.
[3] Mem. G. S. I., IX, pp. 58, 240.

very seldom found; but they have been detected[1] in one case at least. Entomostracous crustaceans are very nearly as common as mollusca; all hitherto found belong to the genus *Cypris*. The other remains of animals hitherto detected have consisted of insects, fishes and reptiles, all of which are fragmentary. Plant-remains abound, but leaves are rare, seeds and fragments of wood being more common; and the most abundant vegetable fossils are the seed vessels of *Characeæ*, of which one species has been described under the name of *Chara Malcolmsoni*. The following is a list of the species of animals hitherto described from the intertrappean beds of the Deccan[2] (common or characteristic species are marked with an asterisk, thus *) :—

ARTHROPODA.

Insecta.

Buprestidæ.—

Lomatus Hislopi, and three other species imperfectly preserved, but supposed to belong to this family.

Curculionidæ.—

Meristos Hunteri, and eight species too poorly preserved for description.

Crustacea.

Cypris cylindrica.
C. subglobosa.
Cypris hislopi.
C. hunteri.
Cypris strangulata.

[1] In Mem. G. S. I., II, p. 213, several forms were referred to the terrestrial genus *Achatina*. Some similar fossils from a French deposit had been placed in the same genus, but it appears more probable that the Indian shells are of fresh-water origin and belong to *Lymnea* or to some allied type.

[2] Q. J. G. S., 1860, pp. 154—189, Pls. V—X. The shells were described by Mr. Hislop himself, the insects by Mr. Murray, the *Cypridæ* by Professor Rupert Jones. Some of the shells collected by Malcolmson had previously been described by Sowerby, Trans. Geol. Soc., Ser. 2, V, Pl. XLVII.

The following are figured on Plate XIV of the present work :—

A.—Fresh-water.

Fig. 1—2, *Physa prinsepii.*
„ 3, *Paludina normalis.*
„ 4, *P. acicularis.*
„ 5, *P. sankeyi.*
„ 6, *P. deccanensis.*
„ 7, *Valvata multicarinata.*
„ 8, *V. minima.*
„ 9, *Lymnea subulata.*
„ 10, *L. telankhediensis.*
„ 11, *L. spina.*
Fig. 12, *Melania quadrilineata.*
„ 13, *Unio deccanensis.*
„ 14, *U. hunteri.*

B.—Estuarine.

Fig. 15, *Pseudoliva elegans.*
„ 16, *Natica stoddardi.*
„ 17, *Cerithium stoddardi.*
„ 18, *Vicarya fusiformis.*
„ 19, *Turritella prælonga.*
„ 20, *Cardita variabilis.*

MOLLUSCA.

* *Melania quadrilineata*, Pl. XIV, fig. 12.
M. hunteri.
Paludina normalis, Pl. XIV, fig. 3.
* *P. deccanensis*, Pl. XIV, fig. 6.
P. wapsharei.
* *P. acicularis*, Pl. XIV, fig. 4.
P. pyramis.
P. subcylindracea.
P. sankeyi, Pl. XIV, fig. 5.
P. takliensis.
P. soluta.
P. conoidea.
P. rawesi.
P. virapai.
Valvata minima, Pl. XIV, fig. 8.
V. unicarinifera.
V. multicarinata, Pl. XIV, fig. 7.
V. decollata.
Bulimus oldhamianus.
Succinea nagpurensis.
Lymnea oviformis.
* *L. subulata*, Pl. XIV, fig. 9.
L. attenuata.
L. telankhediensis var. *peracuminata*, Pl. XIV, fig. 10.
L. telankhediensis var. *radiolus.*
* *L. spina.* Pl. XIV, fig. 11.
* *Physa prinsepii*, Pl. XIV, fig. 2.
Do. var. *elongata*, Pl. XIV, fig. 1.
Do. var. *inflata.*
Unio malcolmsoni.
U. deccanensis, Pl. XIV, fig. 13.
U. hunteri, Pl. XIV, fig. 14.
U. mamillatus.
U. imbricatus.
U. carteri.
Pisidium medlicottianum.

The plants have not been described, with the exception of the *Chara*. Those collected near Nágpúr are said by Mr. Hislop to comprise about fifty species of fruits and seeds, twelve of leaves and five kinds of woods; the only forms mentioned are endogens and angiospermous exogens. The relations of the fossils will be discussed in the sequel, together with the fauna of the other intertrappean deposits.

The whole of the mollusca and crustacea mentioned are freshwater forms; no marine species have been detected associated with them, except in the beds near Rájámahendri, of which a description will be given in the next paragraph. The insects and plants, with the exception of *Chara*, a fresh-water form, are of terrestrial origin. The general prevalence of the pulmoniferous mollusca *Physa* and *Lymnea* appears to indicate that the water was shallow, as these forms live partly at the surface and are not found in deep water: *Cypris*, too, is commonly found in shallow marshes.

Marine beds associated with trap near Rajamahendri.—The outcrops of trap near Rájámahendri (Rajahmundry) are so remote from any other exposure of the Deccan volcanic series, being about 210 miles distant from the nearest point of the great Deccan area north-west of Sironcha, that some doubt would remain as to the identification, despite the similarity of mineral character, had not some of the typical freshwater fossils of the Deccan intertrappean beds been discovered in the Rájámahendri area. The Rájámahendri outcrops occur on both

banks of the Godávari,[1] and consist of an interrupted narrow band of volcanic rocks, chiefly earthy dolerite and amygdaloid of the usual character, extending altogether for about 35 miles from east-north-east to west south-west. On the left bank of the Godávari, traps are seen at Káteru (Kautairoo of the map) just north of Rájámahendri itself, and extend rather more than 10 miles to the east-north-east, resting upon metamorphic rocks whenever lower beds are seen. On the right bank the volcanic rocks appear in two areas, divided by a small alluvial valley; the larger extends for about 10 miles to the westward from Pangadi, 7 miles west of Rájámahendri; and the smaller occurs a few miles still farther west. In these outcrops the beds of the volcanic series rest upon the jurassic rocks of the Ellore region. In both cases the strata overlying the trap are tertiary sandstones (Cuddalore group), and all the beds alike have a low dip to south or south-east. The whole thickness of the volcanic series at this locality, as already mentioned, nowhere appears to exceed about 200 feet, and in places it is not more than 100.

Infratrappean.—At the base of the traps and intervening between the basalt flows and the underlying jurassic sandstone, near the village of Dúdúkúr, twelve miles west of Rájámahendri, about 50 feet of sandstone, white, yellowish or greenish in colour, is exposed. The upper portion is calcareous, and, on the top, there is a band about 6 inches to 2 feet thick of sandy limestone abounding in marine fossils, the most abundant of which is a *Turritella* apparently identical with *T. dispassa* of the cretaceous Arialúr group. If not identical, the two species are very closely allied. A *Nautilus*, about fifteen *Gasteropoda* and eleven *Lamellibranchiata* accompany the *Turritella*, but not a single species, except *Turritella dispassa*, has been recognised as identical either with the cretaceous beds of Southern India or with the eocene fossils of the nummulitic group. The collections have not, however, been sufficiently compared to enable the species to be determined with certainty. Only one single species, too, *Cardita variabilis*, has been recognised as occurring also in the overlying intertrappean bed. Although the whole facies is tertiary, there is a remarkable absence of characteristic genera,[2] and the chief distinction from the cretaceous fauna

[1] The account of these beds is chiefly from manuscript reports by Mr. King. The intertrappean beds were discovered originally by General Cullen and Dr. Benza, and collections of the fossils were made by Lieutenant Stoddart and Sir W. Elliot, and described by Mr. Hislop (Q. J. G. S., 1860, pp. 161, 176, &c.) The infratrappean band was first noticed by Mr. King, (Rec. G. S. I., VII, p. 159).

[2] Amongst the genera identified are *Rostellaria*, several forms of *Muricidæ*, *Volutilithes* near the tertiary *V. torulosa*, *Natica*, *Turritella*, *Dentalium*, *Cytherea* or allied genera (three sp.), *Cardita* (four sp.), *Corbis*, *Pectunculus*, *Cucullæa* and *Ostrea*.

of the upper beds in Southern India is simply the want of any marked cretaceous form. The fauna is distinctly marine.

It is difficult to say whether this bed should be referred to the Lameta group or not. The mineral character is similar, but all known Lameta outcrops are so distant that the identification is somewhat doubtful. The distinctions between the fossils of the Bágh beds and those of the infratrappeans of Dúdúkúr and Pangadi appear too great to be attributed solely to the existence of a land barrier between the two areas; it is difficult to suppose that the two formations can be of the same geological age, and the difficulty consequently arises that, if the Lameta beds represent the Bágh group, they are probably more ancient than the Pangadi infratrappeans. Still the balance of evidence is rather in favour of referring the latter to cretaceous times than to tertiary. They may be of intermediate age.

Intertrappean beds of Rajamahendri.—Upon the fossiliferous limestone described in the last paragraphs a flow of basalt is superposed, varying in thickness from about 30 to about 100 feet. There is an appearance of slight unconformity where the volcanic rock rests upon the sedimentary bed, the surface of the latter being slightly uneven, as if denuded, and the upper fossiliferous infratrappean zone is occasionally wanting. The variation in thickness of the basalt stratum may be due to its having been poured out upon an uneven surface, but it is not quite clear whether this unevenness was due to disturbance of the sedimentary beds before the outburst of the traps. That the denudation of the underlying formations can have been only partial is shewn by the fact that they may be traced between 3 and 4 miles, the upper portion alone being locally absent.

On the left bank of the Godávari near Rájámahendri itself, the infratrappean band has not been observed. The thickness of the lower flow of basalt cannot be clearly ascertained, but it is not less than 40 or 50 feet, and it is probably more. Above this lower flow on both banks of the Godávari, there is found a sedimentary band, 12 to 14 feet thick at Káteru, where it only extends for about half a mile, and about 2 to 4 feet thick in the Pangadi direction, where it has been traced for about 10 miles. The intertrappean bed consists of limestone and marl, and portions abound in fossils. Numerous quarries which have been opened near both Pangadi and Káteru have afforded good opportunities for obtaining fossils, which are difficult to extract from the argillaceous limestone when it is first quarried, but weather out on exposure. About 30 or 40 feet above the fossiliferous limestone of Káteru, another sedimentary bed, consisting of yellow calcareous shale, is seen in one place. It is very thin, and no fossils have been found in it.

Fossils of Rajamahendri intertrappeans.—The following is a list of the species of mollusca described by Mr. Hislop from the Rájámahendri intertrappean beds :—

GASTEROPODA.

Fusus pygmæus.	*Turritella prælonga*, Pl. XIV, fig. 19.
Pseudoliva elegans, Pl. XIV, fig. 15.	*Paludina normalis*, Pl. XIV, fig. 3.
Natica stoddardi, Pl. XIV, fig. 16.	*Hydrobia ellioti.*
Cerithium multiforme.	*H. carteri.*
C. subcylindraceum.	*H. bradleyi.*
C. leithi.	*Hemitoma multiradiata.*
C. stoddardi, Pl. XIV, fig, 17.	*Physa prinsepii*, Pl. XIV, figs. 1, 2.
Vicarya fusiformis, Pl. XIV, fig. 18.	*Lymnea subulata*,[1] Pl. XIV, fig. 9.

LAMELLIBRANCHIATA.

Corbula sulcifera.	*Cardita pusilla.*
C. oldhami.	*Corbicula ingens.*
Psammobia jonesi.	*Corbis elliptica.*
Tellina woodwardi.	*Lucina parva.*
Cytherea orbicularis.	*L.* (*Kellia*) *nana.*
C. wilsoni.	*Nucula pusilla.*
C. wapsharci.	*Arca striatula.*
C. rawesi.	*Modiola*, sp.
C. jerdoni.	*Perna meleagrinoides.*
C. elliptica.	*Lima*, sp.
C. hunteri.	*Anomia kateruensis.*
Cardita variabilis, Pl. XIV, fig. 20.	*Ostrea pangadiensis.*

The most marked feature of this fauna is its distinctly estuarine character. *Cerithium multiforme* appears to be a *Tympanotonus* or *Pirenella. C. leithi* has the characteristic form and sculpture of a *Cerithidea*, and *C. stoddardi* is, at least, as much allied to *Potamides* as to *Cerithium* proper. *Tympanotonus*, *Pirenella*, *Cerithidea* and *Potamides* are all brackish water forms. *Hydrobia* is an estuarine genus, and the fossil called *Hemitoma* closely resembles a species of *Acmæa* found living in creeks in the deltas of Indian rivers. Some of the shells referred to *Cytherea* agree best with the typical forms of the genus (*Meretrix*), many species of which abound in backwaters and at the mouths of rivers, and Mr. Hislop has remarked the similarity between *Corbula oldhami* and a Brazilian species belonging to the estuarine genus *Azara*. There is a complete absence of pelagic shells such as the *Cephalopoda*, no *Echinodermata* or corals are found, and above all, four species are characteristically fresh-water forms, *viz.*, *Physa prinsepii*, *Lymnea subulata*, *Paludina normalis* and *Corbicula ingens*. It is true that the three first are of comparatively rare occurrence, whilst the *Corbicula* is common, and perhaps the last named may have lived in brackish water, as its near ally *Cyrena* does at the present day, whilst

[1] Not included in Mr. Hislop's collections, but obtained since from Kateru.

the purely fresh-water shells were washed down by rivers; but this view is quite in accordance with the theory that the intertrappean beds of Rájámahendri were deposited in brackish water, which was supplied with fresh water by streams, but which was also in communication with the sea.

The mollusca, however, cannot be considered as very characteristic of age. They were compared by Mr. Hislop with the nummulitic fauna of Western India; but, as he points out, no forms appear to be identical, and although *Natica dolium, Turritella affinis* and an unnamed *Cerithium* found in the tertiaries of Sind and Cutch, resemble *N. stoddardi, T. prælonga* and *C. stoddardi,* the intertrappean forms are more closely allied to the cretaceous *N.* (*Mammilla*) *carnatica, T. elicita* and *Cerithium vagans* than to the eocene species mentioned,[1] and other forms might easily be shewn to be affined to those occurring in the cretaceous rocks of Southern India. In the case of *Turritella prælonga* and *T. elicita* the affinity is very great. The shell called *Vicarya fusiformis* appears not to be really congeneric with *V. verneuilli,* the type of the genus,[2] and the latter has now been found to be miocene, not eocene. On the whole, it may be safely asserted that no tertiary alliances of any value have been detected amongst the intertrappean Rájámahendri fossils, and that their relations are rather with the upper cretaceous rocks of Southern India, although the connexion is not strong.

Upper intertrappean beds of Bombay[3].—In the Islands of Bombay and Salsette, and probably farther north on the same line of coast, the trap rocks have an inclination of from 5° to 10° to the westward. The islands are separated from each other and from the mainland to the north by tidal creeks and alluvial flats, whilst between them and the mainland to the eastward is the expanse of water forming Bombay Harbour. In the islands of the harbour, and on the hills between Tanna and Kalyán north of the harbour, the same westwardly dip is displayed, whilst farther to the eastward from Kalyán to the Sahyádri range the traps are horizontal.

[1] When Mr. Hislop wrote, the South Indian cretaceous fossils had not been described.

[2] This was pointed out by Mr. H. M. Jenkins, Q. J. G. S., 1864, p. 58. He also, p. 65, suggested that the Sind beds containing *Vicarya* were newer than eocene, a view since confirmed.

[3] For fuller descriptions of these beds, see Carter, Jour. Bombay Br. Roy. As. Soc., IV, p. 161, and "Geological Papers on Western India," p. 128. It must not be forgotten that Dr. Carter's views as to the relations of the sedimentary beds differ essentially from those stated in the text, with which all other observers agree. See also Buist; Trans. Bombay Geogr. Soc., X, p. 195, and Wynne, Mem. G. S. I., V, p. (193), and VI, p. (385). Besides Drs. Carter and Buist, Dr. Leith and Mr. G. T. Clark have added greatly to our knowledge of the geology of Bombay Island.

About 2,000 feet of horizontal beds are exposed on the flanks of Matherán hill, and a still greater thickness farther to the east in the hills near the Bor Ghât and close to the Great Indian Peninsula Railway line between Bombay and Poona; but as no lower beds than the traps are seen, it is impossible to say how far the lowest strata exposed at the base of the hills are above the bottom of the series. Without closer measurements than have hitherto been made, it is difficult, owing to the numerous breaks in the section, to estimate the precise thickness of the rocks dipping to the westward near Bombay, but taking the average dip at 5°, the whole thickness turned up in 15 miles would be nearly 7,000 feet.[1] This is a minimum estimate; probably the average dip is higher, and the thickness consequently greater. From 1,200 to 1,500 feet of rock are exposed in Bombay Island, so that it is evident that the lowest beds seen on the island are higher in the series than the highest flows seen on the Sahyádri mountains to the eastward, even although some of the higher portions of the range are 4,000 feet above the sea.

The intertrappeans of Bombay are entirely confined, so far as is known, to these higher beds, no sedimentary rocks having hitherto been found amongst the middle portions of the Deccan trap series. It is manifest that the Bombay fresh-water beds belong to a very different horizon from that to which the intertrappeans of Nágpur and the Narbada valley must be assigned. The most important bed is that which underlies the basalt of Malabar hill and Worlee hill, forming the broken ridge along the western or sea face of the island; consequently this stratum is immediately beneath the highest lava flow known to occur anywhere throughout the trap area, for the rocks, as already stated, dip to the west, and no beds higher than those of Bombay have been discovered. It must, however, not be forgotten that the coast north and south of Bombay has not hitherto been examined with sufficient care to make it quite certain that no higher beds occur.

This intertrappean bed on the east side of Malabar hill is in places more than 100 feet thick, and consists principally of soft grey, greyish-blue, brown, and brownish yellow earthy shales, with occasional harder bands, some of which are black and carbonaceous. The greater portion of the bed is evidently formed of volcanic detritus, whether lapilli washed down by water, or sand produced by the disintegration of lava flows, it is difficult to say; very possibly both may have contributed to the formation of the rock. Occasionally, at the top of the deposit, the shale becomes hardened and silicious, as if by the action of the overlying

[1] This appears more probable than the much lower estimate of 4,000 or 5,000 feet given in Mem. G. S. I., VI, p. (151).

basalt. The black carbonaceous shale is locally highly bituminous and sometimes contains small layers of a coaly substance and fragments of mineral resin. Impressions of vegetables abound, although they are but seldom well preserved, and remains of animals are common, the best known being skeletons of small frogs and carapaces of *Cyprides*.

Besides this thick sedimentary band, several thinner beds have been found at lower horizons amongst the lava flows and ash beds of Bombay Island. They are, however, very thin, and except one, which is seen in the quarries of Nowroji hill, south of Mazagaon, they are difficult to detect; indeed, the circumstance of their occurrence has only become known through the careful scrutiny of local geologists, who, living in the town, could take advantage of any excavations for buildings, tanks, roads, &c., to examine the strata exposed. According to Dr. Buist there are five or six sedimentary beds below the thick band of Malabar hill, &c., but fossils have only been found in that exposed at Nowroji hill, where *Cyprides* occur. All these bands consist of shaly beds.

Fossils of Bombay intertrappean beds.—The fossils found at Bombay are tolerably numerous, but hitherto only the *Vertebrata* appear to have received more than a superficial notice. The remains of a fresh water tortoise, *Hydraspis leithi* (*Testudo leithi*, Carter) belonging to the *Emydidæ*, and of a frog, *Rana pusilla*,[1] considered by Dr. Stoliczka an *Oxyglossus*,[2] have been found, the latter in abundance, whilst some bones of a larger frog have been obtained. The *Arthropoda* are represented by three species of *Cypris*, one of which, *C. cylindrica*, is also found in the intertrappean deposits of the Deccan; another species has been called *C. semimarginata* by Dr. Carter, the third is unnamed. *C. semimarginata* is the most generally diffused, but the other forms also occur in great numbers. Only fragments of insects have been found. Mollusca are rare, and the few specimens hitherto procured have been in poor condition; they have been referred to *Melania* and *Pupa*, but with some doubt, and none of the characteristic Deccan forms have been detected. The plant-remains comprise stems, leaves, seeds, and perhaps roots, but very little has been determined, except that endogens and angiospermous exogens are represented.

The life represented by the species named is clearly that of a shallow marsh. The frogs occur in large numbers, and their bodies have evidently been deposited near the spot where they died, as the whole skeleton

[1] Owen: Q. J. G. S., 1847, p. 224.

[2] Mem. G. S. I., VI, p. (387). Dr. Stoliczka shews that the form agrees well with *Oxyglossus* and with no other known existing genus. At the same time, as some of the principal characters by which genera of frogs are distinguished are not preserved in the skeleton, the Bombay frog may have differed greatly from recent *Oxyglossi*. From the species of true *Rana* it is distinguished by the want of vomerine teeth, the large head, and short hinder limbs.

is found perfect; in some cases, as was noticed by Dr. Stoliczka,[1] the skeleton has been dragged along the surface of the shale in which it is embedded, and he suggests with great probability that this was done by wind. The tortoise is a marsh or river form, the nearest living ally, according to Dr. Gray,[2] being a genus found in fresh water in South America.

Origin of the Deccan traps sub-aerial.—After the description of the various sedimentary formations intercalated with the traps or underlying them, the next point for consideration is the mode of origin of the trap rocks themselves. Their volcanic character is sufficiently proved by their composition; precisely similar rocks occur amongst the lavas poured out from recent volcanoes, whilst nothing of the same kind has ever been known to be deposited from water. But the first difficulty which arises, and it is one of very great importance, is to account for the persistent horizontality of the beds. Two observers certainly, Jacquemont[3] and Adolph Schlagintweit[4] have considered that the traps are unstratified, but after the evidence already mentioned as to the differences in mineral character between successive bands, the frequent occurrence of vesicular structure on the upper surface of flows, the presence in abundance of beds of volcanic ash, and the repeated interstratification in the same localities of sedimentary layers, it is unnecessary to refute this view. A much more common opinion, and one which has been supported by numerous excellent geologists, from Newbold downwards, is that the Deccan traps are of subaqueous origin, and it is necessary to shew why this opinion is untenable.

In all cases of subaqueous eruptions, the ejected masses consist of substances very similar to the lava, ashes, scoriæ and lapilli of ordinary subaërial volcanic outbursts, but these materials being thrown out into the water are reduced by the sudden cooling to the condition of a fine powder, which is dispersed and deposited in layers in the same manner as ordinary detritus, so as to form what are known as stratified tuffs.[5]

[1] Mem. G. S. I., VI, p. (393).

[2] Ann. Mag. Nat. Hist., Ser. 4, VIII, p. 339.

[3] "Voyage dans l' Inde," Vol. III, pp. 594-596, &c.

[4] "Report of the Proceedings of the Officers engaged in the Magnetic Survey of India," No. I, p. 6. Reisen in Indien und Hochasien, I, p. 141.

[5] "The volcanic products thus forced out under the sea present, as might be expected, a very different aspect from that of the ashes, scoriæ, and lava from terrestrial volcanoes; the molten lava, coming in contact with the water, is at once broken up into fragments, coarser or finer in proportion to the greater or less cooling power of the water in immediate contact with them, and often in great part instantly converted into fine mud, of a greyish colour when formed from trachytic lava, but more commonly of chocolate or other dark tint, and much denser when produced from the ordinary pyroxenic lava. Beds of this character spread out by the action of the sea, often enclosing shells, fish and other organic remains, become in time consolidated and upheaved, and as they often present an appearance much resembling ordinary volcanic rocks, they have frequently puzzled geologists, who at first found a difficulty in explaining the presence of such fossils in rocks apparently of igneous origin."—D. Forbes: Geol. Mag., 1870, p. 323.

With these tuffs ordinary marine deposits are necessarily intercalated, and both these and the tuffs are usually fossiliferous, the very destruction of life in the waters of the sea, caused by the heat and gases which are evolved during eruptions, ensuring the preservation of those portions of the organism which are not liable to destruction from the temperature of boiling water or the process of decomposition. Now, the volcanic ashes already described as occurring in great abundance amongst the higher beds of the Deccan traps are not, as a rule, stratified in the manner in which beds deposited from water would be. Although they occur in strata intercalated with basaltic lava flows, these ash beds themselves have no internal lamination, except in a few rare instances, in which they are chiefly composed of bole, and may have been formed in the small pools of fresh water so common in volcanic areas. Above all, not a trace of a marine organism has ever been found in any ash bed, or in any rock intercalated with the traps, except in the intertrappean and infratrappean formations of Rájámahendri, in which case the lava has evidently been poured out on the coast, the intertrappean beds, as already shewn, being estuarine, and the infratrappean littoral It may be thought that the prevalence of volcanic conditions would destroy all life in the sea, and thus the absence of marine fossils in the traps may be explained, but even if this view were conceded, (and it is entirely opposed to all that is known of recent submarine volcanic action,) there must have been a great destruction of life at the commencement of the volcanic epoch, and some traces of the animals destroyed would have been preserved.

Relation of Deccan traps to underlying rocks.—The evidence afforded by the characters of the traps and the absence of marine fossils is, therefore, opposed to the hypothesis of a submarine origin, and the relations of the lowest lava flows to the underlying rocks are strongly antagonistic to the idea that the volcanic outbursts were subaqueous. The surface of the older rocks upon which the traps rest is in many parts extremely uneven, the basalt filling great valleys, sometimes as much as 1,000 feet in depth, the form of which shews that they were excavated by subaërial erosion. Admirable examples are seen between Bhopal and Hoshangabád, where the Deccan traps rest upon an extremely uneven surface of Vindhyan rocks.[1] It is true that this uneven surface might have been formed above the sea and then depressed beneath the water, but as periods of depression are always favourable for the accumulation of sediment, we should in this case expect to find aqueous deposits of considerable thickness at the base of the volcanic rocks. It is remarkable

[1] Mem. G. S. I., VI, pp. (240), (242), &c.

that precisely in this uneven ground no deposits whatever are found at the base of the traps, and the general absence of any infratrappean deposit has been noticed in the Southern Maratha country, where also the surface upon which the traps rest is very irregular.

Where the underlying formation consists of the cretaceous Bágh beds, these are, as a rule, conformable to the volcanic series, and it might be thought that in this tract of country the traps were submarine. But every here and there, a spot is found where the cretaceous rocks are wanting, and where the level of the infratrappean surface shews that their absence is due to denudation.[1] In some cases where the Bágh beds are not more than 30 or 40 feet thick, the denudation which has removed them has only extended over a small area, and has scarcely affected the harder rocks beneath, and from the small area, often only a few yards wide, over which the cretaceous rocks have been removed, it is evident that the denuding agent was subaërial erosion. It has also been ascertained that the Bágh beds had been locally disturbed to a small extent, besides having suffered from denudation, before the commencement of the volcanic outbursts. As has already been noticed in the description of the Lameta beds, their relations to the lowest traps are precisely similar to those exhibited by the marine cretaceous beds of the Western Narbada valley; there is the same slight disturbance and local denudation, although, as a rule, the two formations are conformable.

Subaërial origin proved by fresh-water beds.—Lastly, the circumstance that, with the single exception of the estuarine intertrappean band of Rájámahendri, every fossiliferous sedimentary bed intercalated with the Deccan traps is unmistakably of fresh-water origin, is a conclusive proof that all those lava flows which are associated with such sedimentary beds are not submarine. We have thus not only a complete absence of all proof of submarine origin,[2] but clear and unmistakable evidence that the traps were in great part of subaërial formation.

Lower traps not poured out in a great lake.—Another favourite idea with many writers, and especially with Mr. Hislop and Dr. Carter,

[1] Mem. G. S. I., VI, pp. (212), (300), (313), &c.

[2] It may appear to many geologists that an unnecessary amount of space and argument has been devoted to proving a very clear proposition, *viz.*, that the Deccan traps are subaërial. The reason for giving the arguments at length is that a different view has been expressed by many geologists, and repeated within the last few years in the "Memoirs of the Geological Survey of India," Vol. IX, p. 60, &c. A reference to the "Quarterly Journal of the Geological Society of London," Vol. XXX, p. 225, will shew that the arguments used by Professor Judd, to prove the subaërial origin of the volcanic rocks in the west of Scotland and north of Ireland, are precisely the same in many cases as those mentioned above. These views had been urged in the case of the Indian rocks (Mem. G. S. I., VI, p. (145), some years before the publication of Professor Judd's papers.

has been that the lower traps were poured out in a vast, but shallow, fresh-water lake extending throughout the area over which the "intertrappean limestone formation" extends.[1] This hypothesis involves the existence of a lake of enormous size, several hundreds of miles in length and breadth, but shallow throughout. It appears more probable that the lakes in which the Lameta group and the intertrappean beds were deposited were of moderate size, and that they were formed by unequal elevation of different parts of the area prior to the volcanic outbursts, or by the obstruction of the drainage of the country by lava flows. The lake or lakes in which the Lameta beds were formed may have been more extensive, but it has already been shewn that single sedimentary bands intercalated in the traps, can rarely be traced for more than three or four miles, and the character of the fauna, in both the groups of intertrappean formations,—those of Central India and those of Bombay,—is in favour of the animals of which the remains are found having inhabited shallow marshes rather than deep lakes.

Horizontal traps difficult to explain.—We are thus thrown back upon our original difficulty, the horizontality of the Deccan traps. It has been shewn that this is not due to a subaqueous origin, whether marine or fresh-water. At the same time the phenomenon cannot be said to have been thoroughly explained, because no such formation is known to be in process of accumulation at the present day. Many such masses of horizontal stratified traps are, however, found in various parts of the world, and although it is impossible for want of recent examples to demonstrate the circumstances which cause their formation in place of volcanic cones, there is abundant evidence that such traps were in past times a common form of volcanic accumulation, and moreover that

[1] By both the writers named the intertrappean beds of Bombay were supposed to be identical with those of Central India, and both were under the impression that there was but a solitary fresh-water bed which was deposited before any volcanic outbursts took place, which was then covered up by lava flows, and finally separated from the underlying rocks, and broken up by a great sheet of intrusive basalt injected beneath it.

The geologists named would doubtless have modified their views had they been acquainted with all the facts now ascertained with regard to the Deccan traps and the associated sedimentary beds. The conception of a great sheet of intrusive basalt so injected between two formations that it always overlies the one and underlies the other, over an area of thousands of square miles, is quite untenable. It is a physical impossibility that an immense dyke should be injected for hundreds of miles instead of breaking through to the surface. Moreover, the fact that successive sedimentary beds, as in the case at Mekalgandi Ghát, mentioned on page 313, are often of different mineral composition, and the very frequent instances in which the upper surface of a sedimentary band is altered, whilst the lower is unchanged, prove that both lava flows and sedimentary "intertrappean" beds were regularly and successively formed, one above the other, as they now occur.

similar stratified lava flows were not confined to any particular epoch, although several instances are known of about the same geological age as that attributed to the Deccan outbursts.

Volcanic foci.—Assuming therefore, as we are justified in doing, that the horizontal dolerites of Western and Central India precisely resemble modern lavas in everything except their horizontality and the extent of area which they have covered, it remains to be seen what evidence there is of the sources from which this enormous accumulation of molten materials was poured out. The original cones and craters, if any ever existed, must have been the first portion of the volcanic area to suffer from denudation, and it is easy to conceive that subaërial erosion, from eocene times to the present, would have more than sufficed to remove every trace of the loose material of which volcanoes are chiefly composed. Still it is surprising that the inclined beds forming the slopes of a volcanic cone should in no single case have been recognized as having been preserved by being encased in subsequent outbursts of harder materials. Possibly the tendency of great lava streams to sweep away all loose volcanic materials, may suffice, in those cases in which large quantities of lava are poured out, to prevent volcanic cones from forming.

When, however, we look for other evidence of the neighbourhood of igneous outbursts, we find dykes and irregular intrusions abundant in some localities, rare or absent in others, whilst the presence of volcanic ash throughout a large portion of the trap area has already been noticed. The ash-beds, especially when, as usually happens, they form a coarse volcanic breccia, containing blocks several inches in diameter, cannot have accumulated far from volcanic vents, although they may have been transported to a much greater distance floating on the surface of molten lava, than they could have been ejected from the volcano.

A much closer examination of the Deccan area than has hitherto been practicable will be requisite before the distribution of dykes and ash beds can be considered as even approximately known. So far as the country has hitherto been examined, both appear to prevail much more largely in the region near the coast, from Mahableshwar to the neighbourhood of Baroda, than in other parts of the trap area. It is, of course, very often difficult to recognise dykes amongst rocks of precisely similar mineral character, much closer search being needed than is requisite in order to detect volcanic intrusions amongst sedimentary formations. It is only where dykes are large and numerous that attention is likely to be directed to them.

There is one tract of country in which dykes are peculiarly large and abundant. This is in the Rájpipla hills, north-west of Surat. In this

country, over a considerable area, very large parallel or nearly parallel basalt dykes are found, sometimes not more than 200 or 300 yards apart, the general direction being east by north to west by south. The traps are much disturbed, and frequently dip at considerable angles.

To the southward of the Tapti, along the line of the Sahyádri, and its neighbourhood, in Western Khandesh, the Northern Konkan, and the small intermediate native States, a tract of which the geology is unknown, it is probable that dykes may continue numerous for a considerable distance, as their number and size in the Konkan, north-east of Bombay, are especially noticed by Mr. G. T Clark,[1] but intrusions are far from abundant in the lava flows exposed in the higher country east of the Ghâts, although a few occur. At the same time the frequent occurrence of ash beds in the higher traps around Poona and Mahableshwar sufficiently attests the neighbourhood of the old volcanic vents.[2]

North of the Rájpipla hills and of the river Narbada, and west of Baroda, trap dykes are not so common as in the Rájpipla hills, but intrusive masses occur; one of these, forming Matapenai or Kurali hill, about 14 miles south-west of Chota Udepúr, is a mass of grey trachyte or trachy-dolerite, containing enormous masses of granite, evidently derived from the metamorphic rocks through which the mass, when molten, passed on its way to the surface. The siliceous character of the intrusion in this and some other cases is perhaps due to the fusion of quartzose metamorphic rock in the basic dolerite. Another trachytic core was noticed near the village of Pudwani, 18 miles west of Broach. The occurrence of fragments derived from the metamorphic rocks in intrusive dykes is by no means an uncommon occurrence.

It is only natural that far better evidence of volcanic foci is to be found outside the trap area, or in the inliers of older sedimentary rocks exposed within the main boundary, than amongst the lava flows themselves, and it may therefore be useful to point out very briefly the distribution of such intrusive masses so far as the country is known. Commencing to

[1] Q. J. G. S., XXV, p. 164.

[2] Mr. Clark, *loc. cit.*, states that a series of such vents running north and south actually exists in the Konkan. The only reasons for doubting whether his views are quite accurate are that he repeatedly writes of vents, whilst the present cores of the old foci usually stand out as hills, that he apparently looks upon the western dip of the Bombay traps as their original slope, although the inclination of the interstratified sedimentary beds shews that the dip is due to subsequent disturbance, and that he does not appear to be aware that the scarps of the ghâts are due to denudation, and that consequently an immense thickness of beds has been removed from above the surface of the Konkan. His observations on the dykes are excellent and evidently trustworthy.

the north-west, no trap dykes have been found in Sind, where, however, the deposits of older date than eocene cover an exceedingly small area. In Cutch, however, throughout the jurassic rocks, intrusive masses of basalt and dykes of large size abound, and some of the former rise into hills of considerable size.[1] Kattywar has been but little explored, and the abundance of intrusive trap in the lower Narbada valley has already been mentioned. Throughout the northern edge of the trap country in Rajpútána, Gwalior and Bundelkhand, dykes are rare or wanting, but they abound in some of the areas of older rocks exposed in the Narbada valley, and they are especially common in the Gondwána tract, south of the river, in the neighbourhood of the Mahádeva hills. Farther to the eastward they are less numerous, but some occur throughout the upper Son valley, and they gradually die out in Sirgúja and Palamaun (Palamow) only 200 miles west of the ground in which the older lava flows of Rájmahál age are seen, and within less than 100 miles of the Gondwána basins in the upper Damuda valley, which are traversed by basalt dykes probably of the same age as the Rájmahál traps. Passing southwards from Jabalpur and Mandla, however, there is a total absence of volcanic intrusions amongst the Vindhyan and Gondwána formations of Nágpúr and Chánda, and none have as yet been noticed in the neighbourhood of the Pránhita and Godávari between Chánda and Rájámahendri. The country south of the Godávari and north-west of Hyderabád is still imperfectly known, but in the South Máhratta country, and the Konkan near Vingorla, the few dykes which have been observed traversing the unmetamorphosed azoic strata are but doubtfully connected with the Deccan traps. Ashes, moreover, are much less abundant in this region, amongst the Deccan flows, than they are further north.

We have thus abundance of evidence of the former existence of volcanic foci in Cutch, the Rájpipla hills and the lower Narbada valley and probably in the neighbourhood of the Sahyádri range east and north-north-east of Bombay, whilst there is every probability that vents extended to the eastward as far as South Rewah and Sirgúja; but there is no evidence of any having existed in the Nágpúr country or to the south-east. Yet, as the traps are found represented at Rájámahendri, it appears probable that they once extended over all the Godávari valley. Still, it is quite possible that the Rájámahendri outlier may have been

[1] One of these, called Denodhar, was described originally as a volcano. Trans. G. S., Ser. II, Vol. V, p. 315, and the statement that it is an extinct crater has been repeated in numerous geological works. The hill is very probably the basaltic core of an old volcano, but its date is anterior to that of the nummulitic formation. Its crateriform appearance is due to denudation.

originally isolated and derived from a centre which has not been discovered.

It is, however, very clear that the lava flows must have extended to an enormous distance from the vents through which the molten material was poured out. The neighbourhood of Nágpúr and Chánda have been examined so closely that the improbability of any intrusions of igneous rock having been overlooked is much greater than in most parts of the country. Trap-dykes are rarely solitary; they are, as a rule, abundant in the neighbourhood of volcanic foci. It is known that the comparatively moderate outbursts from existing volcanoes flow to great distances from their source. The excessive fluidity of the Deccan traps is proved by their horizontality, for they must have been poured out in immense sheets of but slight thickness, but of great horizontal extension, and it is difficult to form an accurate idea of the distances to which they may have flowed before consolidating. Further observations are necessary before all the sources of the great volcanic series of Western India can be said to have been even approximately determined.

Geological age of the Deccan traps.—The question of the geological age to be assigned to the Deccan volcanic outbursts has been left to the last, because it was desirable to precede it by a full statement of all the facts upon which a conclusion may be founded. The evidence to be recapitulated is twofold, that founded on the affinities of the fossils found in the various intertrappean rocks, and that derived from the relations of the stratified traps to beds above and below them. It is, of course, clear that the traps rest upon cretaceous beds and are overlaid by nummulitics, and the only question is whether the lava flows are cretaceous or eocene.

The most important clue to the correlation of the volcanic rocks with the known series of fossiliferous deposits might be expected to be obtained from the marine beds associated with the volcanic formations at Rájámahendri. This, however, as has been already shewn in the description of the sedimentary beds, proves of little service. So far as is hitherto known, the relations of both the infratrappean and intertrappean faunas are with the cretaceous rather than with the tertiary beds, but the points of connexion, in the latter case especially, are quite insufficient to decide the affinity of the formations.

Turning to the fresh-water fauna of the intertrappean beds, the first difficulty is, of course, the same as in the case of the Gondwánas, the question arises what dependence is to be placed upon terrestrial animals and plants as a guide to geological age. In the case of the Gondwána formations it has been shewn that forms characteristic of particular epochs

in Europe occur in a very different position in the geological sequence in India, and it is, therefore, necessary to be cautious in accepting conclusions founded upon slight evidence. There is a very marked similarity between some of the fresh-water mollusca of the Deccan intertrappeans and species found in some beds of plastic clay age (lower eocene) occurring at Rilly-la-Montaigne in Northern France[1] one species of *Physa*, *P. gigantea*, from the latter locality being considered by some palæontologists identical with the Indian *P. prinsepii*. This identification is, however, to say the least, extremely doubtful, and the fauna of the Rilly beds appears more recent than that of the Deccan intertrappeans. Other resemblances between the plants and fish of the intertrappean beds and those of the London clay have also been indicated, and a *Physa*, said to be allied to *P. prinsepii*, has been found in the nummulitic rocks of the Himalayas, but even the generic identification in the latter case is far from certain.[2] This evidence only suffices at the most to shew an approximation between the age of the Deccan trap and the lower eocene, and is quite insufficient to prove whether the former should be classed as uppermost secondary or lowest tertiary. On the other hand, the very probable connexion already shewn to exist between the Lameta group and the Bágh beds on the one hand, and the occurrence in the Lametas of intertrappean fossils on the other, furnish a connecting link between the lower traps and rocks of middle cretaceous age.

The relations between the traps and the underlying cretaceous beds of the lower Narbada valley have been already described. There is general conformity, with local unconformity, due to slight and apparently subaërial denudation of the underlying beds. In a very few localities also the latter appear to have been disturbed before the formation of the lowest traps. Between the highest volcanic beds and the nummulitic rocks of Surat and Broach, the break appears to be much greater, not only do the tertiary rocks rest upon a largely denuded surface of the traps, but they are in a great measure composed of materials derived from the disintegration of the lava flows, the lowest tertiary beds being frequently coarse conglomerates of rolled basalt fragments, whilst beds, hundreds of feet in thickness, are chiefly composed of agates derived from the traps. This, however, although it proves that great denudation of the volcanic rocks took place during the deposition of

[1] Mem. Soc. Geol. de France, Ser. II, Vol. III, p. 265. The genera found at Rilly-la-Montaigne, are *Cyclas*, *Ancylus*, *Vitrina*, *Helix*, *Pupa*, *Clausilia*, *Megaspira*, *Bulimus*, *Achatina*, *Auricula*, *Cyclostoma*, *Paludina*, *Physa*, *Valvata*. The majority of these genera are terrestrial forms.

[2] D'Archiac and Haime: Desc. An. Foss. Num. de l'Inde, p. 277.

the nummulitic formations, does not necessarily imply a great break and an interval of disturbance prior to the commencement of the tertiary epoch, because the traps, being of subaërial origin, were, unlike most sedimentary rocks, subject to erosion from the period of their formation. The unconformity at the base of the traps, however, is distinctly marked, and appears to shew a great break in the sequence. The lowest tertiary beds near Surat contain fossils which appear to be a mixture of middle and lower eocene forms (Khirthar and Ranikot).[1]

Farther to the westward, in Cutch, the rocks at the base of the tertiary group resting upon the trap are locally conformable, and they have even been considered[2] to be partially volcanic, but, as will be shewn in the next chapter, there can be no doubt that a break, marked by unconformity, exists between the two series. It appears most probable, too, that the lowest tertiary beds are really composed of detritus derived from the volcanic rocks, as all appear to be of sedimentary origin, and no instance has been noticed of intercalation with the lava flows. The great difficulty of distinguishing between volcanic ash and the detritus of igneous rocks when mixed with ordinary sediments, especially where, as in Cutch, the rocks are much decomposed, is too well known to require comment. The beds immediately resting upon the traps are of older date than the nummulitic limestone. The trap rests unconformably on neocomian and jurassic formations.

In Sind the very thin representatives of the Deccan traps may, of course, only represent a small portion of the period during which the volcanic rocks were in process of accumulation further to the eastward. One band rests conformably upon cretaceous beds, the exact horizon of which has not been ascertained, and is overlaid, equally conformably, by strata which are of very old tertiary date, if indeed they be not intermediate between tertiary and cretaceous, whilst a second bed of trap is found about 700 feet lower, interstratified with cretaceous sandstones.

It will be seen, therefore, that whilst it is clear that the Deccan traps were poured out in the interval between middle cretaceous and lower eocene, the evidence tends to shew that the lowest volcanic outbursts were of cretaceous age, because they appear to differ less in age from the middle cretaceous beds of Bágh than the highest traps do from the lower eocene formations of Surat. That an immense period of time was occupied by the accumulation of the successive volcanic outbursts is manifest; long intervals must have elapsed between successive flows in all those cases in which fossiliferous sedimentary beds

[1] For explanation of these terms, see a subsequent chapter on the geology of Sind.
[2] Wynne: Mem, G. S. I., IX, p. 66.

are intercalated, for these intervals were sufficient to enable lakes to be formed and stocked with life, and in other cases for rivers to cut beds in the lava flows, and to fill up those beds with gravel and sand. It is by no means improbable that whilst the lower lava flows were upper cretaceous (turonian or senonian) the uppermost, including the inter-trappean beds of Bombay, may have been contemporaneous with the lowest eocene deposits. As a whole, however, the Deccan trap series appears to be more probably upper cretaceous than tertiary.

Probable conditions prevailing during Deccan trap epoch.— Recapitulating the whole evidence, so far as it is presented to us by the observations hitherto made, we find that a great area of the Indian Peninsula, in times subsequent to middle cretaceous, formed part of a land surface, very uneven and broken in parts, but apparently chiefly composed to the eastward of extensive plains, which, by some slight changes of level preceding the volcanic period, were converted into lakes. There is much probability that springs charged with silica were common either at this epoch or shortly after. The lakes had apparently been drained, and the deposits, which had accumulated in them, had locally been subject to denudation before the first outbursts of lava took place; these occurred at considerable intervals, small and very shallow lakes or marshes being formed in the meantime by the interruptions to the drainage produced by lava flows, or by changes of level accompanying the volcanic eruptions. In these lakes a rich fauna of fish, mollusca, entomostracous crustacea and water plants existed, whilst a varied and probably a rich vegetation occupied the surrounding country. There is evidence of the existence of insects and of reptiles (whether terrestrial or aquatic has not been determined), but hitherto no remains of mammals or birds have been found— a circumstance which by no means proves that they did not exist. Fresh flows of lava filled up the first lakes, and covered over the sedimentary deposits which had accumulated in the waters; but these very flows, by damming up other lines of drainage, produced fresh lakes, so that several alternations of lava and sedimentary beds were produced in places. Gradually the lakes seem to have disappeared; whether the lava flows succeeded each other so rapidly that there was no time for the accumulation of sediment in the interval, or whether, as is more probable, the surface had been converted into a uniform plain of basalt by the enormous lava streams which had been poured out, it is difficult to say, but no further traces of life have hitherto been found until towards the close of the volcanic epoch. It is possible that at the end, as at the commencement of the period, the intervals between eruptions became longer, and the animal and vegetable

life which may have been seriously diminished, or altogether driven out of the country, during the rule of igneous conditions, resumed its old position, but a great change had taken place in the long interval, the old lacustrine fauna had died out, and the animals and plants which now appeared in the country seem to have differed from those which had formerly occupied it. Lastly, in the north-western portion of the area, parts of the volcanic country were depressed beneath the sea, and marine tertiary deposits began to be formed from the detritus of the extinct volcanoes and their products. A great tract of the volcanic region, however, appears to have remained almost undisturbed to the present day, affected by subaërial erosion alone, and although probably for a time at a lower elevation than at present, never depressed beneath the sea-level.

CHAPTER XIV.

PENINSULAR AREA.

TERTIARY ROCKS.

Distribution of tertiary strata in the Peninsula — East coast: Cuddalore sandstones —West coast: Travancore limestones, sands, clays and lignite — Ratnagiri plant beds — Tertiary beds of Guzerat — Eocene beds of Surat — Higher tertiaries of Surat and Broach — Kattywar — Ossiferous beds of Perim Island — Cutch — Subnummulitic group — Gypseous shales — Nummulitic — Arenaceous group — Argillaceous group — Upper tertiary — Jesalmir.

Distribution of tertiary strata in the Peninsula.—The tertiary rocks of the Indian Peninsula cover but a small area, and are confined to a narrow fringe found in places in the neighbourhood of the coast. The ossiferous deposits of the Indian river valleys are now considered post-tertiary, and the geological age of the laterite or iron clay which is found capping many of the Indian plateaus is quite uncertain, and it is, therefore, best to describe all forms of lateritic rock separately.

In the extrapeninsular area, in Burma, Assam, the Punjab, and especially in Sind, on the other hand, there is a superb development of tertiary rocks, and although, for the sake of uniformity of arrangement, it is best to describe the tertiary beds of the Peninsula apart from those found beyond the Indus and Ganges, it must be understood that the only important fossiliferous marine formations in the Peninsula, of later date than the Deccan traps, are found in Western India, and are a mere prolongation to the south-east of the Sind and Cutch tertiaries.

There are but five regions of India in which tertiary rocks will require to be noticed in the present chapter. These regions are all on the outskirts of the peninsular area, and all in which marine fossils have been detected are either along the west coast, or on the border of the Indus valley. In the interior of the Indian Peninsula no trace of a marine tertiary formation has hitherto been detected, and it appears probable that the peninsular area was land during tertiary, as it was for the most part during mesozoic and probably in palæozoic times. The

tertiary outcrops on the margin of Peninsular India may be thus classed—

(1)—East coast of the Peninsula (Cuddalore sandstones).
(2)—West coast of the Peninsula, Travancore (and Ratnagiri ?).
(3)—Guzerat (Surat, Broach, Perim Island, Kattywar).
(4)—Cutch.
(5)—Jesalmir.

Only three of these—the Cuddalore sandstones, the tertiary beds of Guzerat, and those of Cutch—are sufficiently developed or sufficiently known to be of importance; of the other occurrences but little has been ascertained.

East Coast: Cuddalore sandstones.—Along the eastern coast of the Peninsula, from the neighbourhood of Rájámahendri to beyond Tanjore, and probably farther south, a peculiar formation, consisting chiefly of sandstones and grits, is found underlying the laterite which forms a low slope on the edge of the coast alluvium. This sandstone formation has received several local names, but has of late years generally been known as the Cuddalore sandstone,[1] from being well developed in the neighbourhood of the civil station of Cuddalore (Gudalúr) on the coast, about 100 miles south of Madras.

The greater portion of the Cuddalore group, throughout the area in which it is found, consists of gritty and sandy beds, sometimes highly ferruginous, and coloured of various tints of yellow, brown, red and purple, sometimes white or pale coloured, and not unfrequently mottled. In some cases the rock is argillaceous, and occasionally thin bands of clays or shales are interstratified. The beds are soft, loose-textured, and, as a rule, ill-consolidated, being rarely sufficiently compact to be used as building stone. Bands of conglomerate have been found.

As already stated, these beds have been traced throughout a large portion of the east coast. Their most northerly extension known is between Vizagapatam and Rájámahendri. The coast north of Vizagapatam as far as the Chilka lake has not been examined geologically, and throughout Orissa no outcrops of the Cuddalore beds have been detected; but there is a possibility that they may be represented by some clays and sandy beds associated with the laterite of Midnapur.[2] There is rather more probability that the sandstones, grits and clays, already briefly mentioned[3] in the description of the Rániganj coalfield as occurring

[1] For further information, see H. Blanford: Mem. G. S. I., IV, pp. 165-179; King and Foote: *ib.*, pp. (256), (268); and R. B. Foote: *ib.*, X, pp. 59-60.

[2] Mem. G. S. I., I, p. 268.

[3] *Ante*, p. 184.

east of Ráníganj, and extending to the northward as far as Soory in Birbhúm, belong to the same group as the tertiary sandstones of Madras.

From the neighbourhood of Rájámahendri the Cuddalore beds have been mapped at intervals for fully 500 miles to the southward along the coast. They usually form a low slope, dipping at a very slight angle towards the eastward or in the direction of the sea, and are, as a rule, much covered and concealed by laterite. To the westward they rest indifferently upon rocks of various ages, metamorphic, jurassic, or cretaceous, but always unconformably, and they very often terminate in this direction in a low scarp. To the eastward they disappear in places, with their capping of laterite, beneath the alluvium of the coast, but they quite as often, especially to the southward, terminate in a small cliff. Their outcrop is repeatedly interrupted by the broad alluvial valleys of rivers, and in some places, as for nearly 100 miles south of Madras, they appear to be wanting altogether, whilst in other parts of the country they form a broad tract raised above the general level, usually sandy and infertile, occasionally, as near Cuddalore, no less than 25 miles wide from east to west, but in general much less. South of Tanjore these beds have not been mapped, but there is no doubt that they extend for a considerable distance towards Cape Comorin.

From the paucity of sections and the extent to which the Cuddalore sandstones are concealed by laterite and sandy soil, their absolute thickness can nowhere be estimated with accuracy. The scarp in which they terminate to the westward is sometimes as much as 100 feet high, and they must be somewhat thicker than this, but it is doubtful if they attain any considerable thickness. They are perfectly undisturbed, and have all the appearance of being a comparatively late formation.

The only fossils found in the Cuddalore beds consist of exogenous silicified fossil wood, some of which is coniferous, and has been described under the name of *Peuce schmidiana*.[1] The genus *Peuce* is not acknowledged by all palæo-botanists, and it appears too ill defined to justify any conclusions as to the age of the rocks being founded upon its occurrence.

This silicified wood is especially abundant at Tiruvakári (Trivicary), about 14 miles west-north-west of Pondicherry, whence the name of Trivicary grits applied by some writers to the local development of the Cuddalore sandstones. The trunks of trees occurring at this place are of large size, one having been found as much as 100 feet in length, whilst stems 15 to 20 feet long and 5 or 6 feet in girth are not uncommon. They occur prostráte, embedded in ferruginous grit.

[1] Schmidt and Schleiden: "Uber dic Natur der Kieselhölzer," Jena, 1855, pp. 4, 36.

The age and mode of origin of the Cuddalore sandstones are obscure, as but little importance can be attached to the identification of one generic form of coniferous wood. They are quite unconformable to the cretaceous beds, which they overlap in a most irregular manner, as near Pondicherry, where, near the town itself, they form the plateau known as the "Red Hills," and rest on beds of the Arialúr group; 6 miles farther westward and west of the belt of cretaceous rocks, they are seen near Tiruvakári resting on Utatúr beds, whilst a few miles farther west they completely overlap the cretaceous rocks and rest on gneiss. Fragments derived from the cretaceous beds and containing cretaceous fossils have been found near Tanjore. Near Rájámahendri the Cuddalore sandstones similarly overlie the Deccan traps, the jurassic rocks and the gneiss. It is safe, therefore, to conclude that the sandstones are of tertiary age, but it is impossible to assign them a definite place in the tertiary series.

The origin of these rocks is as obscure as their date. Occurring as they do parallel with the coast, it is natural to suppose that they are of marine origin, and have been formed near the shore when the level of the land was somewhat lower than it now is, although the general contour of the coast was the same. But the complete absence, so far as is known, of all marine remains, is not easy to explain. Coarse sandstones and grits are usually unfossiliferous, but in beds which have undergone so little change, some casts of shells, at least, would probably be found in the more argillaceous strata if they were of marine origin. At the same time it is not easy to conceive any other probable mode of formation. It is difficult to suppose that the western coast of the Bay of Bengal can have formed part of a river valley in tertiary times, and it is equally improbable that stratified grits, sandstones, and conglomerates, like those of the Cuddalore beds, can be a form of subaërial wash.

Travancore limestones, sands, clays, and lignite.—The only information yet published on the occurrence of tertiary beds near Travancore is comprised in some notes supplied by General Cullen to Dr. Carter, and published by the latter in his "Summary of the Geology of India."[1] Beneath the laterite of the neighbourhood of Quilon (Kulam), at a depth of about 40 feet from the surface, grey fossiliferous limestone (or dolomite according to General Cullen) is found, partly compact and partly loose and rubbly. This limestone is exposed beneath

[1] Journal, Bombay Br. R. A. S., V, p. 301; and "Geological Papers on Western India," pp. 740, 743, and footnote, pp. 743-744. This footnote is an addition to the original summary. Travancore has not yet been examined by the Geological Survey.

a laterite cliff near the coast 4 or 5 miles north-east of Quilon, and the same rock has been found in the neighbourhood of the town at a depth of about 40 feet in numerous wells, many of which were sunk or deepened by General Cullen for the purpose of ascertaining the presence of the limestone. Further south, near Varkalay, 12 to 14 miles south of Quilon, the cliffs on the coast expose, beneath the laterite, beds of brightly coloured sand and clays with bands of lignite. The sandy beds overlie the lignites and clays. The lignite beds abound in fossil resin and iron pyrites, both in lumps of considerable size.

The limestone contains marine shells in abundance, amongst which the following species were recognised by Dr. Carter:—

Strombus fortisi,	*Ranella bufo,*
Cassis sculpta,	*Conus catenulatus,*
Voluta jugosa,	*C. marginatus,*

Cerithium rude,

besides species of several other genera resembling forms found in the tertiary beds of Sind and Cutch. A species of Orbitolites (?) was also described by Dr. Carter as *O. malabarica.* All the mollusca identified belong to species occurring also in Cutch and Sind, and, so far as is known, in beds of later date than the nummulitic limestone. No plants appear to have been collected from the lignite beds.

Further examination of the Travancore beds and comparison of the fossils is, however, necessary before the age of these rocks can be considered as ascertained with sufficient precision. The interest attached to the subject is, of course, increased by the possibility of these fossiliferous tertiary deposits of Travancore representing the unfossiliferous Cuddalore sandstones; the relations between the two, whether they represent each other or not, will perhaps be determined by tracing both to the southward.

Ratnagiri plant beds.—Another deposit of obscure date and origin has been found beneath laterite at Ratnagiri (Rutnagherry) on the western coast.[1] There is but little evidence to connect this deposit with the Travancore beds, but, owing to some similarity of mineral character, the presence of lignite in both, and the circumstance that both underlie laterite, they have been classed together.

In various quarry and well sections near the town of Ratnagiri, there are found, beneath a considerable thickness of laterite, (35 feet in one case,) white or blue clays with thin carbonaceous seams. Some of the clay is said to be sandy or gravelly; above the deposit is a layer of

[1] Carter: Journal, Bom. Br. R. A. S., V, p. 626, and "Geological Papers on Western India," p. 722, footnote; Wilkinson: Rec. G. S. I., IV, p. 44.

hard ironstone, about an inch thick in places, but said sometimes to be thicker. In the clay and lignite fruits and leaves are found, together with mineral resin and pyrites as at Travancore. No specimens of the organisms found appear to have been collected.

The beds are only a few feet thick (27 in one section measured by Dr. de Crespigny), and rest unconformably upon Deccan trap.

Tertiary beds of Guzerat.—Near the coast of the Gulf of Cambay, in the country between the rivers Tapti and Narbada, a few outcrops of the marine tertiary rocks are found, resting upon the Deccan trap, although the greater part of the country west of the trap area is concealed by a thick coating of "black soil." These outcrops are the commencement of the great tertiary belt which, fringing the coast of Kattywar and Cutch, and extending in patches over the older rocks inland, rises into a lofty range of hills on the western frontier of Sind, and extends to the Himalayas in one direction and through Persia to the Caucasus on the other.

Recently, the examination of Sind has enabled the very fine series of tertiary rocks exposed within that province to be classed in the following groups.[1] :—

1. Manchhar or Siwalik . . .	. Pliocene and upper miocene,
2. Gáj	. Miocene,
3. Nari	. Lower miocene or upper eocene,
4. Khirthar	. Eocene,
5. Ranikot	. Lower eocene,

and some attempt has been made to correlate the groups occurring in other parts of India. Until the fossils can be thoroughly examined, however, it will be impossible to determine the relative position of the different beds in distant regions with accuracy. It is evident that the groups named above are more or less local, and although they are perfectly distinct in parts of Sind, there is a tendency to a passage between all of them in other parts of the province, and it is quite uncertain how far the tertiary rocks beyond the limits of Sind can be arranged in the same sub-divisions. At the same time, as many characteristic fossils are known from all the groups named, these divisions serve as a standard to which the tertiary strata of Western India, and perhaps of the countries to the north-east and east of the Bay of Bengal, may be approximately referred.

The tertiary rocks in Surat and Broach[2] are almost confined to two tracts of country, separated from each other by the alluvium of the

[1] For particulars see Chapter XIX, on the Geology of Sind.

[2] For a fuller description, see Mem. G. S. I., VI, pp. (223)-(227) and (356)-(373).

river Kim, a small stream running to the sea from the Rájpipla trap area. The southern area is smaller, extending about 10 miles north from the Tapti river, and being about 15 miles broad from east to west the other area, between the Kim and Narbada, extends about 30 miles from north-east to south-west, and about 12 miles across where widest. In both, the few good exposures of rock which occur are to the eastward.

Eocene beds of Surat.—At the base of the tertiary formations north-west of Surat are thick beds of ferruginous clay, assuming, where exposed, the characteristic brown crust and pseudo-scoriaceous character of laterite,[1] from which they differ in no respect. These beds at first sight appear to be of volcanic origin, an idea which is strengthened by the neighbourhood of the traps on which they rest, but close examination has shewn that they are really sedimentary deposits, although composed, in all probability, of materials derived from the disintegration and denudation of the trap. With them are interstratified beds of gravel or conglomerate, containing agate pebbles, (the agates being derived from the traps,) and limestone, sometimes nearly pure, but more frequently sandy, argillaceous or ferruginous, and abounding in nummulites and other fossils. The thickness of the whole can only be roughly estimated as between 500 and 1,000 feet.

These beds are well seen on the banks of the Tapti below Bodhán, a village 18 miles east by north from Surat. They extend thence to the northward through Tarkesar to the Kim alluvium, and again north of the Kim to the neighbourhood of a village called Wágalkhor, about 24 miles north-north-east of Bodhán, and 17 east by south of Broach. North of this they appear to be overlapped by higher beds.

The nummulitic limestones and their associates are distinctly unconformable to the underlying traps, and rest upon the denuded edges of the latter. Amongst the fossils found in the lower tertiary beds are *Nummulites ramondi*, Pl. XV, fig. 12, *N. obtusa* (fig. 13), *N. exponens* (or *N. granulosa*, fig. 14,) *Orbitoides dispansa* (fig. 8), and some other species which are common in the Khirthar beds of Sind, together with *Ostrea flemingi*, *Rostellaria prestwichi*, and *Natica longispira*, which in Sind are particularly characteristic of the Ranikot group, and *Vulsella legumen*, Pl. XV, fig. 4,) found in both. Some other fossils have been identified with species found at a higher horizon, but the identification appears doubtful. The nummulitic beds of Surat and Broach may safely be classed as eocene.

Higher tertiaries of Surat and Broach.—Above the limestones and lateritic beds there is found a great thickness of gravel, sometimes

[1] See next chapter.

cemented into conglomerate, together with sandy clay and ferruginous sandstone, often calcareous. These higher beds are poorly exposed in the Tapti river near Galla and Karjan, 15 miles above Surat, and in the Kim river between Kimamli and Elao, about halfway between Surat and Broach, but they are well seen in the stream which runs past Ratanpur, east of Broach. Here they consist chiefly of sandstone, gravel, and conglomerate, with occasional beds of red and white clay and shales. The pebbles in the gravels and conglomerates consist chiefly of agates and quartzose minerals derived from the trap, and from some of these beds near Ratanpur, east of Broach, the agates and carnelians are obtained which have from time immemorial supplied the lapidaries of Kambayat (Cambay). At the base of the tertiary beds in this direction is a coarse conglomerate composed of large rolled fragments of basalt, but it is uncertain whether this bed belongs to the upper tertiary group or to the lower tertiaries, as, owing to the few sections exposed, it is not quite clear whether the lower eocene beds are completely overlapped to the northward, or merely represented by unfossiliferous beds of a different mineral character. Like the underlying beds, the higher tertiary strata have a steady dip to the westward, and the thickness of the whole tertiary series exposed near Ratanpur appears to be between 4,000 and 5,000 feet, but this estimate is based on a very imperfect exposure of the rocks. Of course if, as appears possible, the lower beds are overlapped, the whole of this thickness consists of the upper members of the series.

No nummulites are found in these upper tertiary beds, and the few fossils discovered in them appear to differ from those in the nummulitic limestones below. The commonest organic remains are valves of *Balani*, which are also abundant in the Gáj (miocene) rocks of Sind. The abundance of *Balani* and the absence of *Nummulites* together form strong reasons for believing that the upper beds of Surat and Broach are of later date than eocene.

It is far from certain whether any pliocene beds are found in Eastern Guzerat. They occur in Kattywar and on Perim Island in the Gulf of Cambay, and further search may detect them in Surat and Broach.

Kattywar.—Very little indeed is known about the tertiaries of the Kattywar peninsula.[1] A belt of rocks, of later age than the Deccan traps, rests upon the volcanic series, and forms a fringe of varying width, extending throughout the coast line from the Gulf of Cambay to beyond Porbandar, and probably to the Gulf of Cutch. This fringe is

[1] The few details given are from a manuscript report by Mr. Theobald, and from Dr. Carter's "Summary of the Geology of India;" Jour. Bombay Br. R. A. S., V., pp. 300, 306, 313; and "Geological Papers on Western India," pp. 696, 737, 743, 756, &c.

generally from a mile to about 12 miles broad; but the tertiary beds extend farther inland in places, as opposite the Gir and near Porbandar. They probably also, as in Cutch, lap round the older rocks and reappear to the northward on the borders of the Ran.

Some nummulitic limestone occurs near the base of the tertiary series, and above the limestone there is found a series of argillaceous beds, consisting chiefly of blue clay with bands of sandstone and shelly grit and coarse rubbly limestone, the latter containing amongst other fossils *Balani* and *Venus granosa* (Plate XVI, fig. 7,) both of which are in Sind common in the Gáj (miocene) beds. The clays are of considerable thickness, for at Gogo, on the east coast of Kattywar, a boring was made in them to a depth of 344 feet without any lower rocks being reached. With these clays ossiferous sandstones and coarse conglomerates are said to be associated. If these ossiferous beds, as is possible, represent the Manchhar (or Siwalik) group of Sind, the representatives of the Manchhar and Gáj beds must be interstratified in Kattywar;—by no means an improbable circumstance, for, as will be seen, they pass completely into each other in Sind.

Above the clays and ossiferous sandstones are horizontal beds of limestone and calcareous grit, with occasional layers of clay. One form of this rock is the Porbandar stone, called miliolite by Dr. Carter, largely used for building in Bombay, and mainly composed of *Foraminifera*. This limestone is extensively false-bedded; it is porous, soft, and easily worked. The only fossils found besides *Foraminifera* are land shells of recent species, of which a few occur in the upper beds where the *Foraminifera* are scarce. The age of this formation is uncertain, and it may be post-tertiary, but as alluvial deposits rest upon its abraded surface, it is for the present classed as possibly of late tertiary age.

Ossiferous beds of Perim Island.—The small island of Perim[1] in the Gulf of Cambay, opposite the mouth of the Narbada, but nearer to the coast of Kattywar than to that of Broach, has become famous from the circumstance of fossil bones having been discovered in considerable quantities upon its shores. The island is simply a reef of rock about 1½ miles long, barely half a mile broad at high water, and covered with blown sand. This island itself is surrounded by an extensive reef, dry at low water, and composed partly of conglomerate containing rounded blocks of sandstone, varying from 3 feet in diameter downward, and partly of a coarse sandstone with agate pebbles. Nodular concretionary pebbles of argillaceous sandstone and rolled fragments of fossil wood,

[1] By some European writers on geology and zoology, this island is confounded with another of the same name, but far better known, in the Straits of Babelmandeb at the entrance to the Red Sea. For a description of the geology of the Indian Perim Island and references to former describers, see Mem. G. S. I., VI, pp. (180), (373).

bored by *Teredo*, occur with the large boulders. Both forms of rock are calcareous. Some fine sandstones also occur.

The beds are in general horizontal, and they are, as a rule, much obscured by a deposit of fine mud. Bones occur in the coarse sandstone and in the conglomerate, and the following species of mammals have been identified[1]:—

Mastodon latidens (Pl. XVII, fig. 4).	*Brahmatherium perimense* (Pl. XVIII, fig. 5).
M. sivalensis (fig. 6),	*Camelopardalis*, sp.
M. perimensis (fig. 3).	*Capraperimensis.*
Dinotherium indicum.	*Antilope*, sp.
Acerotherium perimense.	*Sus hysudricus.*
Rhinoceros, sp.	

These beds appear to be slightly older than the typical Siwalik strata.[2]

Cutch.—The tertiary rocks in the Cutch (Kachh or Kach) peninsula occupy a belt varying in breadth from about 4 miles to 20, between the alluvium near the coast and the older rocks in the interior of the country. Tertiary formations also fringe the Deccan traps and jurassic beds on the borders of the two openings by which the Ran[3] to the north of Cutch communicates with the sea east and west of the province[4]; and patches of the same tertiaries are found here and there on the shores of the Ran, not only in the main region of Cutch itself, but also around the detached hilly tracts or islands, Pachham (Putchum), Kharir (Kurreer, &c., and in Wagad (Wagur). The evidence of unconformity between the eocene rocks and the Deccan traps is, therefore, very strong in Cutch, for the former existence of numerous volcanic vents of the Deccan age throughout the jurassic area is proved by the presence of intrusive cores of basalt, and it is almost certain that the greater part, if not the whole, of the jurassic region must have been overflowed by trap in later cretaceous times.[5] The lava flows must have been, however, completely swept away from the surface of the country, and the underlying jurassic rocks exposed, and probably in places largely eroded, before the eocene marine beds were deposited. Despite this strong evidence of unconformity, there is every appearance, along the southern border of the trap area, of the tertiary beds resting conformably on the lava flows of the Deccan period.

[1] Lydekker: Rec. G. S. I., IX, p. 91.

[2] The relations of the mammaliferous later tertiary deposits of India will be discussed in the chapter on the Siwaliks of the sub-Himalayan region.

[3] See Chapter XVII.

[4] Cutch, it should be remembered, is an island in the monsoon, when the Ran is covered by water.

[5] This view is opposed to Mr. Wynne's opinion. He considers that the lower eocene beds are conformable to the traps, and that the overlap is due to the traps never having existed in Northern Cutch.—Mem. G. S. I., IX, p. 72.

The tertiaries of Cutch are far better known than those of Guzerat and Kattywar; the materials for the first descriptions of marine fossils from the later Indian deposits having been furnished by the rocks of the present province. Attention was first directed to the Cutch tertiaries through the labours of Captain Grant, who carried with him to England a considerable collection of tertiary organic remains, together with the jurassic fossils mentioned in a former chapter. In accordance with the ideas prevailing amongst geologists at the time, he separated nummulitic rocks from the true tertiaries on his map,[1] and the same distinction was preserved in the description of the fossils, but subsequently all the forms described were classed as eocene by MM. D'Archiac and Haime.[2] The rocks of Cutch were mapped in 1867-69 by Messrs. Wynne and Fedden, and described by the former[3]: it was found that several distinct groups could be recognised, and that the fossils of these groups differed. It was afterwards discovered that the groups corresponded very closely to those subsequently determined in Sind, and although some of the fossils described as tertiary by Sowerby in the appendix to Captain Grant's Memoir were apparently derived from beds interstratified with the nummulitic limestone, a large proportion are from a higher horizon, and are not in all probability older than miocene. The succession (descending) of the rocks in Cutch, according to Mr. Wynne, is the following, the probable Sind representatives[4] being appended in each case. The supposed European equivalents differ somewhat from those originally suggested[5] before the corresponding beds in Sind had been examined:—

	Cutch.		Sind.	European equivalents.
	Alluvium, blown sand, &c.		Alluvium, &c.	*Pleistocene and recent.*
TERTIARY.	Upper tertiary (unconformity)	200 to 500 ft.	Manchhar	*Pliocene and upper miocene.*
	Argillaceous group	800 to 1,200 „	Gáj	*Miocene.*
	Arenaceous group	130 „	Nari (?).	*Lower miocene and upper eocene.*
	Nummulitic group	700 „	Khirthar	*Eocene.*
	Gypseous shales	100 „	Ranikot	*Lower eocene.*
	Subnummulitic	100 „	Ranikot	*Lower eocene.*
	Stratified traps		Trap	*Upper cretaceous.*

Subnummulitic group.—This group consists chiefly of peculiar soft argillaceous beds of purple and red, mottled with white, laterite of various kinds, and coarse sandstones. There are also some shales with

[1] Trans. Geol. Soc., Ser. II, Vol. V. pp. 300, 302, Pl. XX, XXIV, XXV, XXVI.

[2] Descr. An. Foss. Gr. Numm. de l'Inde.

[3] Mem. G. S. I, IX, pp. 66-81, &c.

[4] See subsequent chapter on Sind.

[5] Mem. G. S. I., IX, p. 48.

impressions of leaves and carbonaceous layers, and occasionally with gypsum. The beds of this horizon are distinguished by brilliancy of colouring; white, red, lavender, purple, and orange tints prevailing.

Some of the peculiar argillaceous beds have a distinctly volcanic aspect, but as they are much decomposed, it is impossible to say that they are really of eruptive origin. The occurrence of these peculiar beds away from the traps, in places where there is good reason to suppose that the traps were removed by denudation in pretertiary times, and the fact that beds reconsolidated from trap fragments must, when decomposed, frequently be undistinguishable from a disintegrated eruptive rock, render it probable that these soft mottled beds are of sedimentary origin and composed of volcanic detritus. Fossils are rare in the sub-nummulitic group, which extends along the southern edge of the traps in Cutch, overlapping the volcanic rocks, however, near Lakhpat to the westward, and resting upon jurassic rocks. The same group is represented in several small patches, also deposited upon jurassic beds, on the borders of the Ran, both on the mainland of Cutch and on some of the detached hills or islands, especially south of the hills in Pachham, Kharir, Bela, and Chobar, and intervening in the hollow between two ranges on the first-named. The group is nowhere more than about 200 feet thick, and it frequently does not exceed 20 feet. Alum is manufactured at Mhar in Western Cutch from a pyritous shale associated with the present sub-division.

Above the subnummulitic beds there are in places from 50 to 100 feet of fine laminated shales, bituminous and often pyritous, with fragments of wood and leaf impressions. All the above rocks are, by Mr. Wynne, classed apart from the true tertiaries, and with the bedded traps, It appears more probable, however, and more in accordance with the sequence in Sind, where, as in parts of Cutch, the beds are, as a rule, perfectly conformable, to consider the main break in the series as taking place between the traps and the next formation in ascending order.

Gypseous shales.—This is a local and unimportant sub-division, not more than from 50 to 150 feet in thickness, occurring in Western Cutch around the Gaira hills, and in a few other places. It consists of shales with calcareous nodular bands, with some beds of laterite, and with much gypsum. Some of the marly beds abound in *Nummulites* and other *Foraminifera* with oysters, &c.

Nummulitic.—The next group is of more importance, being the representative of the massive nummulitic limestone of Sind. In Cutch these beds consist of pale yellow and white impure limestones in bands

of no great thickness, interstratified with marls and sandy beds. The upper portion consists chiefly of marls, limestones being more abundant below. *Nummulites* and *Alveolinæ* abound, and Echinoderms of several kinds; corals and mollusca are locally common. The nummulites of Cutch are, however, almost confined to the western part of the province, and occupy a band extending from Lakhpat, at the extreme north-west of the Peninsula, around the Gaira Hills, the western termination of the Deccan trap range in Cutch.

Arenaceous group.—Upon the nummulitic limestones and their associates there is usually found a thin and unimportant band of light coloured or white sand and sandy shales, having at the base some finer silty shales, dun or blue in colour. These sandy beds are soft, friable, and obliquely laminated. In the lower portion of the group the carapace of a small crab and casts of bivalve shells have been found, in the upper part impressions of dicotyledonous leaves occur. This group, like the nummulitic beds, is only found in Western Sind.

Argillaceous group.—The next group in ascending order is the most important of all the Cutch tertiary beds, being the best developed and the most fossiliferous, and it is this group which yielded the bulk of the fossils described as "tertiary" in the appendix to Captain Grant's paper, although it appears probable that there was amongst these fossils some admixture of species from a lower horizon. Until the whole of the Cutch and Sind fossils are thoroughly compared and determined, some doubt must remain as to the original horizon of a few Cutch species, but when the forms are common to the Gáj beds of Sind, and are not known to occur in older formations, it may fairly be inferred that they are probably restricted to the same horizon in Cutch.

The rocks of the argillaceous group consist of sandstones at the base with a few nodular marly and ferruginous beds often containing *Turritellæ*, *Venus granosa* (Plate XVI, fig. 7) and *Corbulæ*. Above the sandy beds are marly limestones and shales, next calcareous grits, and then a considerable thickness of shales, clays, and marls. The most fossiliferous beds are the marly limestones and shales. In mineral character, as in fossils, these beds appear precisely to resemble the Gáj group of Sind. The argillaceous group is more extensively developed in Cutch than the nummulitics are; it is found not only in the west of the province around the extremity of the jurassic and trap area, but eastwards, resting upon the subnummulitic group, as far as the neighbourhood of Mándvi, or about half way across the province. To the westward, however, the present group is overlapped by the next in ascending order.

Upper tertiary.—This is apparently the representative of the Siwalik rocks in the Sub-Himalayan tract, and of the Manchhar beds in Sind; it is widely developed in Cutch, and covers a large area, but it is very ill seen, being greatly concealed by alluvial deposits. The principal beds are conglomerate, more or less ferruginous, at the base, followed in ascending order by thick brown sands and obliquely laminated, nodular, calcareous and sandy clays. Marine beds with large oysters are intercalated, as in Southern Sind. It will probably be found on further examination that this uppermost tertiary group in Cutch, as in Sind, passes down into the underlying sub-division in places, although to the eastward the latter appears to have been denuded before the deposition of the former. The "upper tertiary" group extends throughout Southern Cutch from east to west, resting on the older tertiaries to the westward, but gradually overlapping them and the traps to the eastward, and resting upon jurassic rocks in the extreme east of the province.

Jesalmir.—About 30 miles west-north-west of Jesalmir, on the road to Rohri in Sind, the track, which from Jesalmir as far as this passes over jurassic rocks, crosses a steep scarp of nummulitic limestone of no great height. The rock has a very low dip to the westward, and rests unconformably upon the jurassic beds: it is traced for a few miles further west before it disappears beneath the sands of the "Thar," or desert of blown sand-hills, which forms the western boundary of Sind. A few small patches of limestone, however, appear from beneath the sand-hills further to the westward, and it is probable that the rock continues in this direction to Rohri, where there are low hills of the formation. The scarp extends for many miles to the north-east; to the south-west it is covered by sand-hills.

In the limestone some of the common nummulites, such as *N. ramondi* (Pl. XV, fig. 12), *N. beaumonti* and *N. spira*, occur in abundance. These are amongst the forms characteristic of the great nummulitic limestone (Khirthar) formation of Sind. The outcrop in fact, although east of the Indus alluvial area, is evidently merely an outlier of the extra-peninsular rocks. Whether it is more extensively developed to the northward in Baháwalpur remains to be ascertained.

CHAPTER XV.

PENINSULAR AREA.

LATERITE OR IRON CLAY AND LITHOMARGE.

Laterite — General characters and composition — Varieties of laterite, high-level and low-level types — Lithomarge — Reconsolidation of laterite — Infertility of lateritic surface — Distribution and mode of occurrence of the high-level laterite or iron clay in the Western Deccan, Southern Máhratta Country, hills near the Máhánadi valley, Karakpur hills, Bundelkhand and Rájmahál hills — Distribution, &c., of the low-level laterite — Theories of origin of high-level laterite — Geological age — Possible Ohypothesis of origin —Origin of low-level laterite — Its age.

Laterite.—All who have paid any attention to the geology of India must be familiar with the term "laterite," and no one can have travelled far in India without meeting with the substance itself. Although it is difficult to conceive that a rock, so widely spread in India, can be peculiar to the country, and to some other parts of South-Western Asia,[1] it is uncertain if anything precisely similar has hitherto been detected elsewhere; and nothing of the kind is known in Europe. The description of laterite, given in many geological works, is far from accurate,[2] although the rock has been well described by several Indian geologists.[3]

[1] It is said to be extensively developed in Malacca and Sumatra, and some occurs in Burma. Voysey states that it is found at the Cape of Good Hope. It is an extraordinary fact that no laterite has been detected in Abyssinia, where the rocks throughout a large area of country are precisely similar to those of the Bombay Deccan.

[2] For instance, in Lyell's Elements (edn. 1865), pp. 598-600, this substance is classed with igneous rocks, and thus defined: "A red jaspery, brick-like rock, composed of silicate of alumina and oxide of iron, or sometimes consisting of clay, coloured with red ochre." At the same time we are indebted to Lyell for the very valuable suggestion, that the rock may be derived from the disintegrated detritus of lava and scoriæ washed down by water.

[3] It would be difficult to give a description of any rock more clear and accurate than Newbold's account of the laterite of Bidar: J. A. S. B., XIII, p. 989 (1844). See also J. A. S. B., XIV, p. 299, and the description of the rock generally by the same author in his "Summary of the Geology of Southern India": Jour. Roy. As. Soc., VIII, p. 227 (1846).

The descriptions of laterite scattered through the writings of various Indian geologists are too numerous to quote. Amongst the more important are the following:—

Buchanan: Journey from Medras through Mysore, Canara, and Malabar, II, p. 440 (1807).

From the very large area in India, which is superficially covered with laterite, it becomes an important formation; and a treatise on Indian geology would be imperfect without a full description of the rock. The geological age is, in many cases, obscure. Although there can be but little doubt that some forms of laterite date from tertiary, and perhaps from eocene, times, other forms are unquestionably post-tertiary, some being in process of formation at the present day; and as the rock is usually unfossiliferous, it appears best to describe all the varieties together at the commencement of the section relating to post-tertiary or quarternary rocks.

General characters and composition.—Laterite, in its normal form, is a porous argillaceous rock, much impregnated with iron peroxide, which is irregularly distributed throughout the mass, some forms of the rock containing as much as from 25 to 35 per cent. of metallic iron.

Stirling: As. Res., XV, p. 163 (1825).
Christie: Edinb. New. Phil. Jour., VI, p. 117 (1829); and Mad. Jour. Lit. Sci., IV, p. 468 (1836).
Calder: As. Res., XIX, p. 4 (1833).
Cole: Mad. Jour. Lit. Sci., IV, p. 100 (1836).
Voysey: J. A. S. B., XIX, p. 273 (1850).
Kelaart: Edinb. New Phil. Jour., LIV, p. 28 (1853).
Carter: Jour. Bom. Br. R. A. S., IV, p. 199 (1852); V, p. 264 (1857).
Aytoun: Edinb. Phil. Jour., IV, p. 67 (1856).
Buist: Trans. Bom. Geog. Soc., XV, p. xxii (1859).
The subject has also been frequently treated in the Memoirs of the Geological Survey, especially in Vol. I, pp. 69, 265, and 280; II, p. 78; IV, p. (260); X, p. 27; XII, pp. 200-221 and 224; XIII, p. (222).

[1] The only analysis of laterite which appears to have been published is one by Captain James of a very richly ferruginous variety from Rangoon: J. A. S. B., XXII, p. 198.

The result given is the mean of three analyses made in the Laboratory of the School of Mines, London:

Soluble in acids.	
Peroxide of iron	46·279
Alumina	5·783
Lime	·742
Magnesia	·090
Silica	·120
Insoluble in acids.	
Silica (dissolved by potash)	6·728
Silica (by fusion)	30·728
Lime, iron, and alumina	2·728
Combined water alkalies and loss	6·802
	100·000

This is equal to 32·4 per cent. of metallic iron.

This iron exists either entirely in the state of hydrated peroxide (limonite,) or else partly as hydrated and partly as anhydrous peroxide. The surface of laterite after exposure is usually covered with a brown or blackish-brown crust of limonite, but the rock, when freshly broken, is mottled with various tints of brown, red, and yellow, and a considerable proportion sometimes consists of white clay. The difference of tint is evidently due to the segregation of the iron in the harder portions, the pale-yellow and white portions of the rock, which contain little or no iron, being very much softer, and liable to be washed away on exposure. Occasionally, the white portions have a brecciated appearance, and consist of angular fragments in a ferruginous matrix. In this case, the rock has not unfrequently a compact texture resembling jasper, but it is never so hard as a purely silicious mineral.

The iron peroxide not unfrequently occurs in the form of small pisolitic nodules, which, when washed out, are sometimes employed as iron ore. Veins and nests of black manganese have been observed by Newbold [1] in some laterites of the Deccan.

In many forms of laterite, the rock is traversed by small irregular tortuous tubes, from a quarter of an inch to upwards of an inch in diameter. The tubes are most commonly vertical, or nearly vertical, but their direction is quite irregular, and sometimes they are horizontal; they are usually lined throughout with a crust of limonite, and are often filled with clay, except near the surface. Besides these, there are sometimes horizontal cracks, sometimes expanding into small cavities, and giving an appearance of irregular stratification to the formation. In

The following are assays of the quantity of iron contained in the portion of laterite soluble in acids.

The first five and No. 8 have been made by Mr. Mallet for the present work; the other three are from the paper on the Laterite of Orissa, Mem. G. S. I., I, p. 288.

			Percentage of metallic iron.	Percentage of iron peroxide.
1	High-level laterite overlying Deccan trap, Amarkantak		35·6	50·8
2	Ditto	from Main Pat, Sirgúja . .	16·6	23·7
3	Ditto	from Baplaimali plateau, Kalahandi, south of Sambalpur . . .	15·	21·4
4	Ditto	from top of Moira hill in the Karakpur range, south of Monghyr .	28·3	40·4
5	Ditto	from Mahuagari hill, Rájmahál hills	15·8	22·5
6	Laterite (? high-level) from Kattywar, Western India		22·8	32·5
7	Low-level laterite	from Daltola, Cuttack, Orissa . .	24·5	34·9
8	Ditto	from near Cuttack . . .	25·6	36·5
9	Ditto	from Tanjore	23·4	33·4

The difference between high-level and low-level laterite will be explained subsequently.

[1] J. A. S. B., XIII, p. 992.

the more massive forms of laterite some horizontal banding is usually present, the cavities being, however, beneath the surface, usually filled by clay, more or less sandy. The rock, when first quarried, is so soft, that it can easily be cut out with a pick, and sometimes with a spade, but it hardens greatly on exposure.

The exposed surface, whether vertical or horizontal, is characteristic and peculiar. It is extremely irregular, being pitted over with small hollows, caused by the washing away of the softer portions, and generally, though not always, traversed by the tubes and cavities just described; and, at times, it is so much broken up by small holes as to appear vesicular, whilst the crust of limonite forms a brown glaze, often mammillated or botryoidal, so that the rock has a remarkably scoriaceous appearance, and bears a very curious resemblance to an igneous product. It is not surprising that many observers should have looked upon laterite as volcanic; for not only does it present a remarkable superficial resemblance to a scoriaceous lava flow, but it is found, in several parts of India, associated with basalt and other igneous rocks. As will be shewn presently, however, laterite is never an original form of igneous rock; it is in all cases either produced by the alteration of other rocks, sometimes igneous, sometimes sedimentary or metamorphic, or else it is of detrital origin.

Varieties of laterite, high-level and low-level types.—Several writers have urged that the term "laterite" should be restricted to one form of the rock—that to which the name was originally applied by Buchanan.[1] This is the kind so extensively developed on the west coast of India, where it forms the surface rock of the country over wide tracts of the low lands near the sea. The particular locality in which the rock was first described by Buchanan has not been re-examined by other geologists, but there can be no reasonable doubt that he applied the name to a detrital variety. Before proceeding further, it will be well to explain the differences between the two forms.

The high-level laterite, sometimes known as non-detrital laterite, and distinguished by Mr. Foote as iron clay,[2] is found extensively on the highlands of Central and Western India. It is a rock of fine grain, and, apart from the irregular distribution of the iron, of nearly homogeneous structure, and not sandy. For this form the term "iron clay" was used by Voysey, one of the earliest describers, but he did not restrict the term to this variety; and he employed the same name for the laterite of Nellore, a low-level detrital form.

[1] l. c. note, p. 318.

[2] M. G. S. I., XII, p. 201.

The low-level or detrital laterite, which covers wide tracts in the neighbourhood of both coasts, generally contains grains of sand, and may often be recognised by including small rolled fragments of quartz, and occasionally larger pebbles. It is less homogeneous in structure than the high-level form, and it passes, by insensible gradations, into ferruginous sandy clay or gravel. It usually contains, in considerable quantities, small pisolitic concretions of iron peroxide, and occasionally it assumes the form of pisolitic iron ore, or of lateritic gravel, a mixture of small concretions and sand. The high-level laterite also contains pisolitic concretions in places, but they are not so generally present as in the low-level variety.

There are unquestionably some reasons for using different terms to designate these two forms of rock; and all geologists who consider that by the name of a rock not only its composition and structure, but also its origin, should be indicated, are justified in employing distinctive terms for the two, if they consider the difference of origin clearly made out. Unfortunately, the very use of two terms involves the hypothesis that the high-level form of laterite, containing no sand grains, has been produced simply by subaërial alteration of basalt or some other rock, whilst the low-level laterite is a formation of entirely different origin. This may be true, but, as will be shewn presently, it is not proved, and in some cases the origin of the high-level laterite appears to be clearly detrital. The fact is, that the two varieties pass completely into each other; both are often precisely similar in composition and structure, and specimens taken from one are frequently quite undistinguishable from those broken off from the other, although the rocks can usually be distinguished *in situ* by careful examination. How difficult it is, at times, to ascertain whether laterite is of detrital origin or not, is well shewn by the beds, which, as mentioned in the last chapter (p. 340), occur interstratified with the nummulitic limestones and gravels near Surat. These beds are sedimentary, for, in one of them, marine fossils were found; yet they are not in the least sandy, and they closely resemble the laterite or iron clay of the Bombay Deccan. The resemblance is so close, that, when these laterite beds were first examined by the Survey, they were supposed to be volcanic rocks, altered by surface action. The mistake, it should be added, was partly caused by an apparent intercalation of basalt and nummulitic limestone, subsequently found to be due to faulting.

Moreover, there is this strong reason for not using different names for the two varieties; the term "laterite" has been so generally applied to both forms of the rock by geologists, that it is no longer possible to

restrict it to one. When it becomes necessary, in the following pages, to distinguish between the two forms, they will be called "high-level" laterite and "low-level" laterite, these names, which merely refer to the position occupied by the two varieties on the highlands or near the coast, not involving any theory of the origin of the rock. Each will require separate notice, in order to explain its distribution and the theories proposed to account for its origin; but before proceeding to these questions, there is another form of ferruginous clay, very generally associated with laterite, which requires explanation.

Lithomarge.—Both forms of laterite frequently appear to pass into the underlying rock, whether this be igneous, metamorphic, or sedimentary. In the case of basalt, or gneiss underlying laterite, the upper part of the lower formation is decomposed, and forms a clay, which is impregnated with iron, by the water trickling through the laterite above, and becomes a kind of lithomarge, passing by insensible gradations into laterite itself. In fresh sections, where the detrital low-level form of laterite is the overlying rock, the limit of the two can usually be traced without difficulty, but surfaces which have been exposed for a length of time are generally covered with more or less of the limonite glaze and the lithomarge can no longer be distinguished from laterite.[1] This lithomarge is always more ferruginous above than below; it varies in colour from red through yellow to white, being usually mottled, and not unfrequently coloured purple or lilac in patches, and a few pipes often occur, produced apparently by the percolation of water.

Another form of lithomarge, found in many places, and especially to the northward, beneath the high-level laterite, and occasionally below the low-level form also, consists of hardened clay, sometimes sandy, and generally highly ferruginous, which shews no tendency to pass into the underlying rock, although it usually exhibits unmistakable transition into the laterite above. In these cases, the laterite and lithomarge together form a group of beds, superposed, as a rule unconformably, upon older rocks of various kinds. In some instances, as in Bundelkhand, this infra-lateritic formation contains pebbles,[2] and there is every reason for believing that it is a rock of sedimentary origin. The importance of this form of lithomarge, as a clue to the origin of laterite, will be seen in the sequel; for there is every probability in this case that the laterite is merely the lithomarge, altered by surface-action. In some cases, the present form of lithomarge contains hæmatite or limonite in

[1] Mem. G. S. I., I, p. 283, &c.
[2] Mem. G. S. I., II, p. 86.

considerable quantities,[1] sufficient to enable the mineral to be collected for iron ore, as in Bundelkhand, near Jabalpur, and on the eastern flanks of the Rájmahál hills.

Reconsolidation of laterite.—One peculiarity possessed, to an eminent degree, by all forms of laterite, is the property possessed by broken or detrital fragments of being recemented into a mass, closely resembling the original rock. Laterite itself has great powers of resisting atmospheric disintegration, being, in fact, produced by long action of the atmosphere upon various ferruginous clays; but the underlying formation, whether trap or gneiss, decomposes, and is slowly washed away, until the cap of laterite, originally horizontal, falls down, and becomes reconsolidated on the irregular surface, which it still covers. This is one way in which reconsolidation takes place; another is when broken fragments are washed down by rain and streams to a lower level, at which they become recemented.

Infertility.—The surface of the country composed of the more solid forms of laterite is usually very barren, the trees and shrubs growing upon it being thinly scattered and of small size. This infertility is perhaps due, in great part, to the rock being so porous that all water sinks into it, and sufficient moisture is not retained to support vegetation. The necessary result is, that laterite plateaus are usually bare of soil, and frequently almost bare of vegetation. Of course, this barrenness is by no means universal; soil sometimes accumulates on laterite caps, and some of the more gravelly or more argillaceous varieties support a moderate amount of vegetation. Still the general effect of the rock is to produce barrenness.

Distribution and mode of occurrence of high-level laterite.—The high-level laterite is chiefly developed on the Deccan plateau, and especially on the highest portions of the Sahyádri range, and the spurs running from the Ghâts. It forms a cap on the uppermost traps exposed on the plateau, but it is also found at lower elevations, the lower beds being, however, as a rule, but of small extent or thickness. The summit bed, as it is termed by Mr. Foote, is not more than 50 to 90 feet in thickness in the Southern Máhratta country, and it is about the same at Mahábleshwar, but it is said to be from 100 to 200 feet thick at Bidar, north-west of Hyderábád. It occurs at varying heights above the sea, 4,700 feet at Mahábleshwar being probably the highest point, whilst at several places in the Southern Máhratta country it is found capping ridges and isolated hills from about 2,000 to nearly 3,500 feet above the sea, but it always overlies the highest lava flow in the country. At

[1] Mem. G. S. I., II, p. 81; XIII, p. 241.

Matheran, near Bombay, and on some neighbouring plateaus, there are caps of laterite at about 2,000 feet above the sea, but these do not belong to the summit bed, as the traps on the tops of these hills are not high in the series. Some of the laterite caps are very extensive; the bed at Bidar is said to be 28 miles long from west-north-west to east-south-east and 22 miles broad, and the area of laterite at Kaliani, 40 miles west of Bidar, is of even greater extent.[1]

The greater portion of the trap area in the Deccan has not been closely examined, but, so far as is known, laterite is of rare occurrence, except near the Western Ghâts and in the Southern Máhratta country. A few very small caps are found south-west of Nágpúr, in South-East Berar, and probably similar small outliers occur here and there along the south-eastern margin of the volcanic region. Farther to the north-east, laterite occurs at Amarkantak, and on the eastern outliers of the Deccan traps, at Main Pat and Jumira Pat in Sirgúja, on the former being from 100 to 200 feet thick. North of the Narbada also, in Rewah, Bundelkhand, and in other States as far west as Guzerat, laterite is found, sometimes as much as 200 feet in thickness, capping outliers of the trap series.

In all the localities hitherto mentioned laterite occurs resting upon the Deccan traps, but not only does the high-level laterite overlap the traps, and rest upon older rocks, but it is found in places some hundreds of miles beyond any existing outlier of the volcanic series. Instances of this kind have been noticed by various observers in the Southern Máhratta country,[2] the same laterite bed being continued apparently, in some cases, from the trap surface on to the transition or metamorphic rocks,[3] whilst numerous outliers on the older formations are known to exist. Caps are said also to occur at high elevations on the Dambal or Kupputgode hills, east of Dharwar, and on hills in the neighbourhood of Bellary and Kadapa.[4] More to the north-east, in the high grounds of Patna, Kalahandi, Bastar, Jaipur, &c., between the Máhánadi and Godávari, caps of laterite, 50 to 100 feet thick, occur on many of the higher hills[5] at elevations of between 2,000 and 4,000 feet above the sea. The most eastern exposure known to occur in this neighbourhood is on the Kopilas hill about 2,050 feet above the sea, and 12 miles nearly due north of Cuttack.[6]

[1] Newbold: Jour. R. A. S., VIII, p. 228.

[2] Newbold: J. A. S. B., XIII, p. 996; J. R. A. S., VIII, p. 228; Foote: Mem. G. S. I., XII, pp. 205, 217, &c.

[3] Foote: l. c., pp. 205, 217.

[4] Newbold: J. R. A. S., VIII, p. 228.

[5] Ball: Rec. G. S. I., X, p. 169.

[6] The information of the occurrence of laterite on Kopilas hill was obtained by Mr. Ball from Dr. Stewart of Cuttack.

On the Chutia Nágpúr plateau to the northward, a great expanse of laterite is found, at elevations varying from 2,000 to 3,000 feet above the sea in several places, and especially to the north-west of Jashpur[1]; it differs, however, from the usual high-level laterite, in covering hills and valleys alike, and is probably, in part at least, a reconsolidated or secondary formation. Still, in places, it caps ridges and peaks in the usual manner. Leaving, for the moment, the Rájmahál hills, which require separate notice, a thick mass of laterite occurs on Moira hill, the highest peak of the Karakpur range, south of Monghyr, at an elevation of 1,500 feet. Turning thence westward, caps of the same rock are found, outside of the trap area, at several places in Bundelkhand,[2] and at two near Gwalior,[3] all on the highest ground of the country.

Besides the above-mentioned localities, there are some of the hills of Southern India where laterite has been reported to occur, but there is always a difficulty, unless the locality has been carefully examined, in determining the nature of the formation, since ferruginous clays, with but little of the true character of laterite, and due solely to the decomposition of gneissic rocks, have occasionally been described under the name. Such is certainly the case with the Nilgiris, one of the localities mentioned by several geologists. No well-authenticated occurrence of laterite is known at an elevation exceeding 5,000 feet above the sea.

Rajmahal Hills.—There is, however, a very important bed of this rock on the Rájmahál hills in Bengal.[4] These hills, like the highlands of the Bombay Deccan, are composed of bedded basaltic traps, and, as in the Deccan, the very highest bed consists of laterite; Mahuagarhi, the highest plateau in the range, 1,655 feet above the sea, being capped by this formation. The laterite in the Rájmahál hills is, in places, as much as 200 feet thick, and it slopes gradually from the western scarp of the hills, where it attains its highest elevation, to the Ganges plain on the east. Here too, as in the Deccan, there is, in places, an apparent passage from basalt into laterite, but the latter rock to the eastward is distinctly identical with the low-level laterite of Bengal, Orissa, and Southern India, and is clearly of detrital origin; whilst even at considerable elevations in the hills, fragments derived from the shales, which are interstratified with the basaltic flows, are found imbedded in the laterite, so that, as no distinct line has ever been drawn between the beds at different elevations, we appear in this case to have a passage from the high-level into the

[1] Ball: Rec. G. S. I., X, p. 170, note.

[2] Mem. G. S. I., II, p. 82.

[3] Hacket: Rec. G. S. I., III, p. 41.

[4] These hills have been described already; see p. 165. The laterite has been but briefly noticed; see Oldham: J. A. S. B., 1854, XXIII, p. 273; Ball: Mem. G. S. I., XIII, p. (222).

low-level laterite, and reasons for supposing that both were originally of sedimentary origin. The case, it should be remembered, is not clearly proved, the laterite of the Rájmahál country not having been specially examined with a view to test the connection between the beds to the eastward and those to the westward, but the two appear to be parts of the same formation,[1] and it is certain that both are, in this instance, detrital.

The evidence hitherto collected is insufficient to justify the conclusion, that the high-level laterite once formed a continuous bed, occupying the whole surface of the Indian Peninsula from the Ganges valley to the neighbourhood of Madras, but the manner in which caps now occur upon isolated peaks and ridges clearly shews that these caps formed part of a bed once much more extensive, and of which only a few remnants have been left undenuded. It is difficult, in presence of the great amount of denudation which has taken place since the laterite caps were part of a more or less continuous bed, to escape the conviction, that the high-level laterite must be of considerable geological antiquity.

Distribution, &c., of low-level laterite.—Before proceeding to discuss the very difficult subject of the origin of laterite, it will be best to point out the general distribution of the more sandy and typical variety found at low elevations, and especially in the neighbourhood of the coast. On the west coast of the Peninsula laterite has not been observed in the lowlands, or the Konkan, north of Bombay[2]; it appears, however, a little farther to the southward, between Bombay and Ratnagiri, and extends thence throughout large tracts of the low country intervening between the Sahyádri range and the sea, as far as Cape Comorin. It does not, of course, cover the whole surface; in many places it has been cut away by streams, so that the lower formations

[1] There is a possibility that the connexion between the high-level laterite of the Deccan and the low-level laterite of the eastern coast is not confined to the solitary instance of the Rájmahál hills, although no other case of passage can be traced which is equally well marked, and in some cases, as at Kopilas near Cuttack, the difference in level is very great; but, as will be seen, the low-level laterite of the eastern coast rises gradually from the neighbourhood of the sea, at a slope which, if continued inland, would connect the bed with the high-level formation. The latter is of much greater antiquity than the low-level bed, but the process of formation may have been continuous, the rock now found at a higher level being first formed, and that at a lower elevation being gradually consolidated, as the lower portion of the country was raised above the sea. It should be remembered that the higher part of the country, in all probability, was never depressed below the sea-level. This idea of the whole laterite being one continuous formation appears to have occurred to Newbold.—J. R. A. S., VIII, p. 240.

[2] Except near Surat, where the outcrops are of nummulitic age, or much older than the Konkan laterite in general. The rock differs from all superficial laterite, in being distinctly intercalated between other beds.

are exposed, and in parts of the country it appears to be wanting. The greater part of the region, however, has never been mapped geologically, and no details of the distribution of laterite are available, except in the country between Ratnagiri and Goa.

Here the rock appears to form a plateau, having a general elevation of 200 to 300 feet above the sea. On the coast it terminates in cliffs, the trap being exposed beneath it. The plateau extends for from 15 to 20 miles inland, and it is cut through by numerous rivers and streams, in all of which the trap is exposed, but at Ratnagiri, between the laterite and the traps, the lignite and clays are found, which were mentioned in the last chapter. Farther inland, the laterite is found at a higher elevation than near the coast, so that the rock appears to have a low slope towards the sea. The laterite is distinctly of detrital origin, and even conglomeratic in places; the thickness of the formation is considerable, but no exact measurements have been recorded, except at Ratnagiri, where it amounts to 35 feet, probably less than the average. It is evident that the plateau formerly extended much farther to the eastward, and it probably covered the whole of the country as far as the base of the Sahyádri range; for caps of laterite are found in places on the trap hills, and masses, reconsolidated from the detritus of the principal beds, are found at lower levels.

South of Malwán, the underlying rock is no longer trap, but gneiss, or some other metamorphic formation. The laterite appears to be similar to that of the Bombay Konkan. In Travancore, it overlies the fossiliferous tertiary beds, already mentioned.

On the east coast of India, laterite occurs almost everywhere, rising from beneath the alluvium, which fringes the coast, and sloping gradually upwards towards the interior, but this laterite is a much less massive formation, as a rule, than the rock of the western coast; it is seldom more than 20 feet in thickness, and it is often represented by a mere sandy or gravelly deposit, not more than 4 or 5 feet thick. Where it is thicker, the lower portion usually consists of lithomarge, produced by the alteration of the underlying rock. The laterite is frequently conglomeratic, and includes large, rounded, or subangular fragments of gneiss and other rocks; good instances being found at Trichinopoly, at many places near Madras, amongst which are the Red Hills, 7 miles to the north-west of the city, and around the detached hills north-west of Cuttack, in Orissa. In the Madras area, quartzite implements of human construction have been found in the laterite[1] in considerable numbers.

[1] For additional details of the laterite near Madras, see Mr. Foote's account, Mem. G. S. I., X, pp. 27-58.

The fringe of laterite is of very unequal width. In places, it forms a broad, low slope, stretching for many miles from the edge of the alluvium; in other places, it only remains as caps upon the older rocks. In one form or another, however, it appears to be traced, at short intervals, from Cape Comorin to Orissa, and thence northward, through Midnapur, Burdwan, and Birbhúm, to the flanks of the Rájmahál hills, where it is well developed, and where, as already noticed, it appears to pass into the high-level laterite.

The low-level laterite is not confined to the neighbourhood of the coast. It is found, frequently in patches, over many parts of the country, but these patches are rarely of large size, and they often appear to be due to local peculiarities, such as abundance of iron in the rocks, or reconsolidation of fragments derived from a bed of high-level laterite. Many such lateritic deposits are rather of the nature of ferruginous gravel than of true laterite. The small pisolitic nodules, so characteristic of some forms of laterite, are found abundantly in the older alluvium of the Ganges valley, and in many other superficial deposits in the plains of India; and wherever they are sufficiently abundant, they appear to become cemented with the accompanying sand and clay into a rock, closely resembling laterite in many of its peculiarities.

Theories of origin of high-level laterite.—Having thus stated, as briefly as is consistent with the object of affording a tolerably complete account of the rock, the distribution and mode of occurrence of the different varieties of laterite, the question of the manner in which this rock has been formed, in different parts of India, must next be considered. The subject has already been noticed as difficult, the difficulty arising from the fact that the rock has evidently undergone a considerable amount of change, both chemical and structural. The difference between laterite when first cut from the quarry underground and the same rock after exposure is well marked; the rock becomes harder, and the hardening appears not merely due to the desiccation of the argillaceous constituents, but also to a change taking place in the distribution of the peroxide of iron, the change being shewn by the colour becoming darker, and by the surface being covered with a glaze of limonite. Whether the anhydrous iron peroxide, which occurs in some forms of high-level laterite, becomes converted, by exposure, into hydrated peroxide, has not been ascertained; on this and other questions much light might be thrown by careful chemical analysis. But it is quite clear that the process of segregation of the iron has tended greatly to obscure any structure which may have existed originally in the rock, and that this segregative action is constantly in progress. It has already been stated

that iron is dissolved out of the laterite, and re-deposited in the underlying lithomarge, where the latter is merely an altered form of the rock beneath; and it is a common circumstance, in some forms of laterite, to find pisolitic nodules of hydrated iron peroxide, evidently due to segregation. These facts, and the process by which the surfaces of the rock, and of the tubes by which it is traversed, become coated with a glaze of limonite, render it evident that a transfer of iron oxide from one part of the rock to another is continually going on.

One view, which has been held by several good observers, and which has been strongly supported by Mr. Foote's examination of the laterite, or iron clay, in the Southern Máhratta country, is, that the high-level laterite is simply the result of the alteration *in situ* of various forms of rock, and especially of basalt, by the action of atmospheric changes.[1] Many of the dolerites of the Deccan contain iron in the form of magnetite, and large quantities of magnetic iron sand are found in the beds of streams, which flow over the traps, whilst bands, both of magnetite and hæmatite, are common locally in the metamorphic rocks. The gradual change from doleritic trap into laterite has been noticed by several observers,[2] and, so far as the Deccan alone is concerned, the evidence in favour of laterite being merely the result of atmospheric change, acting upon very ferruginous volcanic rocks, appears so strong, that, if there were no conflicting phenomena, it might be accepted as a satisfactory explanation. At the same time, there are some difficulties, to which attention was first called by Captain Newbold[3]; and although Mr. Foote[4] has shewn that they are not insuperable, still they should not be overlooked, because the apparently sedimentary origin of the rock in Bundelkhand and elsewhere tends to invalidate the conclusion, that the high-level laterite is merely the result of surface change.

The main argument, it should be remembered, in favour of supposing the high-level laterite of the Deccan to be merely altered dolerite is, that the two rocks are seen to pass into each other. This fact, which is unquestionably established, may be considered proof that laterite *may* result from the alteration of basalt, or a similar rock, but it is, of course, insufficient evidence to shew that such is the origin in all cases. It is always possible that the upper portion of the laterite is, in each case, of extraneous origin, and that the surface of the basalt beneath has been

[1] Some writers, of whom the best known is Dr. Carter, have supposed that the low-level laterite has originated in the same manner by the alteration *in situ* of basalt or other rocks, but in this case the detrital origin of the rock is unmistakable.

[2] Voysey: J. A. S. B., XIX, p. 274; Foote: Mem. G. S. I., XII, p. 202, &c.

[3] J. A. S. B., XIII, p. 995; Jour. Roy. As. Soc., VIII, p. 237.

[4] l. c., p. 203.

affected by the infiltration of iron, in the manner already described when explaining the origin of lithomarge. Numerous instances are found, on the other hand, in which the laterite rests upon the surface of basalt, which is either hard and unaltered, or soft and decomposed, without any appearance of a passage from one rock to the other. But this, again, is no proof that the laterite above the unaltered trap is not itself the result of alteration of a different lava flow; all that it shews is, that the non-lateritic rock beneath is not susceptible of the same change. It is clear that the evidence afforded by the circumstance that doleritic trap sometimes passes into laterite, and sometimes does not, is insufficient to decide the question, as to whether the latter is derived from the former, by a process of chemical alteration.

It has been stated that magnetite occurs in many of the Deccan dolerites, but, until far more analyses have been made, it is impossible to say whether any of these rocks contain as large a proportion of iron as the laterite. It is probable that some may, but it is certain that so large a proportion of iron as 15 or 20 per cent.[1] in any basalt is exceptional; yet this is not above the average amount in the Deccan laterite. At the same time, the larger percentage may, perhaps, be explained by a process of concentration, some of the other constituents of the rock having been removed in the process of change, but not the iron. There is, however, in opposition to this explanation, the fact, that the iron is evidently dissolved out of the laterite at present, since iron peroxide is re-deposited on the surface of pipes, &c., and in the underlying lithomarge.

One difficulty, to which especial attention was drawn by Captain Newbold, is the complete absence in the laterite of those nodules, large or small, of various forms of silica, such as agate, jasper, and crystalline quartz, so frequently found in the different forms of trap. It is difficult to understand, if laterite simply results from the alteration *in situ* of the Deccan dolerites, why no amygdaloidal structure, especially where the nodules contain so indestructible a mineral as agate, should be detected in the altered rock. Mr. Foote suggests[2] that, in the case of the summit bed, which appears to rest upon the highest traps, the absence of amygdaloidal structure may be due, in the first place, to the lava flow, now converted into laterite, having been of a peculiarly dense nature (and such dense beds do certainly occur in the Deccan traps, indeed they cannot be said to be rare, although they do not, as a rule,

[1] That is, of metallic iron; 15 per cent. of iron corresponds to 19·3 per cent. of protoxide, and 21·4 per cent. of sesquioxide.

[2] l. c., p. 203.

preserve their non-vesicular character over large areas); and secondly, to the fact that, being the uppermost flow, the water which percolated it did not contain silica in sufficient quantity to form siliceous nodules in the vesicular hollows. He also points out that the underlying bed, into which the summit bed laterite is seen to graduate in several sections, is a very argillaceous rock, without vesicular cavities or enclosed minerals.

One conclusion is clear. If the high-level laterite of the Deccan has been produced by the alteration *in situ* of volcanic rocks, only particular varieties of such rocks are capable of undergoing the alteration. If all were similarly liable to be converted into laterite at the surface, the occurrence of that rock would be more general, and less restricted to particular elevations. The great difficulty in the way of explaining the origin of the high-level laterite, so widely spread in Málwa and the Deccan, by a simple process of atmospheric alteration, is, in brief, that the hypothesis demands the occurrence, over an enormous area of country, of a volcanic rock (whether a tuff or a true lava flow is immaterial), of peculiar and unusual composition, containing a much larger proportion of iron than usual, and wanting the amygdaloidal structure, so common in the Deccan traps. This difficulty, it must be remembered, is, so far, only a reason for caution in coming to a conclusion; it does not shew that the hypothesis of alteration *in situ* is impossible.

The great extension of the laterite beyond the trap area may, of course, be explained, by supposing that the highest volcanic stratum covered a wider surface than any of the inferior lava flows; but in some cases, as in that of the Gauli plateau, south of Belgaum,[1] where a bed of laterite at a lower level than the summit bed was traced by Mr. Foote on both sides of the Mahádayi ravine, passing into the underlying trap to the northward and into metamorphic rocks to the south, this theory is untenable; and in this case, if the laterite be the result of alteration alone, the southern portion must have been formed from gneissic rocks. It is difficult to understand how two rocks, so totally dissimilar in constitution as dolerite and gneiss, can have produced precisely the same rock, by a simple process of disintegration *in situ*.

On the other hand, the difficulties in the way of supposing the high-level laterite to be sedimentary are considerable. The idea of its being a marine deposit can scarcely be entertained; there is not a shadow of evidence in any part of India to render it probable that the whole of the great trap plateau has been beneath the sea in tertiary times. It is inconceivable that fluviatile deposits should be so enormously extended, yet so thin. One objection, which at the first glance appears

[1] Mem. G. S. I., XII, p. 217.

important, is apparent rather than real. It is that a sedimentary deposit could not be formed on the highest portions of the country, because there could be no higher land in the neighbourhood, from which the sediment might be derived, whilst the singularly small amount of disturbance, which the Deccan rocks have undergone, renders it improbable that any great relative change of elevation has taken place. But it must be remembered that laterite is a rock which resists atmospheric action far more than most forms of doleritic trap; this is shewn by the manner in which hard, unaltered caps of laterite rest upon softened and decomposing basaltic rocks; and, consequently, the portions of the plateau, which were originally highest, if not capped by laterite, may have disintegrated more rapidly under atmospheric influences than those protected by the lateritic formation, until the latter remained forming the highest ridges, long after the unprotected portions had been swept away.

The evidence afforded by the laterite outliers in Bundelkhand[1] is distinctly opposed to the theory of alteration *in situ*. The whole group, laterite above, ferruginous clay, frequently containing sand and pebbles, below, is found indifferently capping trap and Vindhyan sandstones. Now, whatever may be the case with dolerite and gneissic rocks, no conceivable process of alteration could convert a purely quartzose sandstone, like the Vindhyan, containing a mere trace of iron, into an argillaceous rock, with 20 per cent. of iron entering into its composition; and the circumstance that the lower portion of the lateritic group is clearly detrital, proves that the laterite is not an altered outlier of the trap.

It appears almost impossible to separate the Bundelkhand laterite from the high-level laterite of the Deccan. Lithologically and stratigraphically the two rocks are identical. There can be no reasonable doubt that the trap once occupied the surface of the ground now cut out into valleys by the feeders and main streams of the Son, Narbada, and Máhánadi, and that Bundelkhand, with Málwa to the north, were united with Mandla and Sirgúja into one plateau of horizontal trap rocks. If this be conceded,—and it appears impossible to doubt it,—the caps of laterite near Saugor, occupying precisely the same relative position as those at Amarkantak and Main Pat, may fairly be considered part of the same bed; and the Rewah outliers, which are probably either beyond the original range of the trap, or else on ground which was above the general trap level, must be referred to the same origin. Now, the Amarkantak and Sirgúja laterites are not merely similar

[1] Mem. G. S. I., II, pp. 79–86.

in every respect to the other Deccan high-level outcrops of the rock, but they appear to be connected, by a series of small caps at intervals, with the typical formation of the Southern Máhratta country. There may be a break in the chain; the distances are too great for any safe conclusions to be formed; all that can be done is, to indicate the probabilities. It appears a fair inference that, if the Bundelkhand laterite is of aqueous origin, the rock of Amarkantak and the Deccan is the same.

The laterite of the Rájmahál hills is separated by so great a break from that of Sirgúja, and the Rájmahál traps are so much older than those of the Deccan, that it is impossible to say whether the Rájmahál laterite is of the same age as that of Central and Western India. Lithologically it is identical, and, like the Deccan laterite, it occurs, in part at least, at a considerable elevation, whilst its sedimentary origin has already been mentioned.

It will thus be seen that, despite all the observations which have been made on the high-level laterite of the Deccan in the course of the last fifty years, it is still impossible to say that this rock has been proved to be simply the result of atmospheric action on the traps and metamorphic rocks of the country, and it is equally unproved that it is due to sedimentary action. Before attempting to reconcile some of the difficulties, a few words may be devoted to the probable age of the formation.

Geological age.—The geological age of the high-level laterite must, of course, remain undetermined, until the mode of formation has been more definitely ascertained. If the rock be merely the result of surface alteration, it may be of any date subsequent to the termination of the volcanic outbursts; indeed, as has been justly pointed out by several observers, it must still be in process of formation. But, as its occurrence in the form of a few isolated caps shews that it was once a much more extensive formation, it must have existed before the denudation of the area, by streams, had much advanced; and, therefore, it must have formed, in part at least, soon after the termination of the volcanic eruptions. The great similarity between the high-level laterite and the beds of the same rock, interstratified with the nummulitic limestones and gravels of Guzerat and Cutch, tends to suggest the possibility, that the two are contemporaneous, and also that they may have been produced in the same manner, with, however, this important distinction, that the Guzerat beds are marine, whilst there does not appear to be any evidence in favour of supposing that the highlands of the Deccan were submerged during any portion of the tertiary period. Had they been submerged, the amount of denudation, which the traps must have undergone, would, in all probability, have caused the high-level laterite to be more distinctly

unconformable. At the same time, it is far from clear that the laterite is truly conformable to the highest trap flows. It has been hitherto assumed, rather than proved, that all the beds of laterite, at lower elevations than the summit bed, are of later age. Of course, on the theory of the laterite being merely an altered form of the traps, the occurrence of laterite, at various elevations, presents no difficulty; but if this rock be of any definite date, it is clear that extensive denudation must have reduced the level of such hills as Matheran, the uppermost beds of which are at least 2,000 or 3,000 feet below the highest volcanic flows, before the laterite was deposited. Nevertheless, the laterite of Matheran, although apparently non-detrital, may be a secondary product. This question of conformity to the highest traps requires, in fact, further investigation.

Possible hypothesis of origin.—The following hypothesis[1] may, perhaps, meet some of the difficulties above-mentioned; it is only suggested as a possible explanation, and by no means as a perfect theory. At the close of the Deccan trap period, the country must have been an immense plain, formed by the latest lava flows. But it has already been shewn that the quantity of volcanic ash, interstratified with the lava flows, increases amongst the upper and later flows, and it is highly probable that scoriæ and lapilli continued to be showered out, at intervals, after the outbursts of lava had ceased. Numerous cones, too, composed for the most part of ash beds, may have been left, so that an immense quantity of loose, incoherent materials must have been spread over the surface of the country. The laterite might, perhaps, be simply this loose ash, changed by chemical action; but, granting this view, it would be difficult to understand the detrital nature of such laterite beds as those described in Bundelkhand, and it is also not easy to account for masses, 200 feet thick, accumulating so far from the main volcanic vents, as to be beyond the area of the enormously extended lava flows. The quantity of iron, also, appears excessive. It is more probable that the laterite has been formed from the disintegrated tuffs and scoriæ, rearranged by the action of water. For a considerable period after the close of the volcanic eruptions, until the denuding action of water had established a system of river valleys, all rain falling on the surface of the country, and washing down the loose materials from a higher to a lower level, can have done little more than fill up hollows.

[1] This hypothesis was, to some extent, suggested in the late Sir C. Lyell's "Elements of Geology," 6th edition, 1865, p. 598. The rocks, however, to which Sir C. Lyell applied the term "laterite," differ materially from the Indian formation, and appear to be chiefly forms of bole. For some instructive remarks on the formation of ferruginous clays from volcanic detritus, see Phil. Trans., 1858, p. 711, already quoted in the chapter relating to the Deccan traps.

For, although the country must have been singularly level, still, as no fluid can run down an absolutely horizontal plane, the upper surfaces of the lava streams must have been slightly inclined, although the angle of inclination was very small. The presence of hollows is, indeed, proved by the previous existence of lakes. Possibly, the reason why high-level laterite is now found chiefly on the outskirts of the trappean area in the Southern Máhratta country, Mandla, Sirgúja, Bundelkhand, &c., is, that these tracts were rather lower in position than the main volcanic foci north of Bombay and in Eastern Guzerat. The peculiar circumstance, that the laterite now caps hills towering above the whole of the remaining country, is easily explained by the fact, already noticed, that laterite resists the disintegrating action of the atmosphere very much longer than any form of basaltic rock.

There is still a great difference between the composition of all scoriaceous volcanic tuffs and that of laterite, for which the above hypothesis fails to account. The fine ashes showered out from volcanoes are, however, easily decomposed, as is proved by the well-known fact of a few years sufficing to render such ashes fit to support a rich vegetation; and as it has been shewn that a decomposed basalt is easily converted into laterite, it is reasonable to suppose that volcanic scoriæ of similar composition to basalt are susceptible of the same change. But the quantity of iron still needs explanation. It is easy to suggest ferruginous springs, or fumeroles, from which crystals of specular iron might be deposited, as in the well-known cases around Vesuvius, but still one objection, already urged, against considering the laterite the result of simple alteration of one extensive lava flow, or ash-bed, remains; this is the difficulty of believing that the iron could have been so generally and equally distributed. It is not impossible that the scoriaceous accumulations, forming the cones of the old volcanoes and the loose ash-beds distributed over the country, were peculiarly ferruginous; and it is easy to understand, if the iron was in the state of either magnetite or specular iron, that it would resist disintegration longer than the felspathic and pyroxenic ingredients of the volcanic rocks, because it does so at the present time, and it is found unaltered in the streams, which wash away the detritus of disintegrated basalt. Another fact to be noticed is, that those deposits which contained less iron originally would be liable to remain unconsolidated, and would consequently be easily washed away, whilst the more ferruginous portions of the detritus would alone possess the power of being converted into hard, indestructible laterite.

One fact must on no account be overlooked. The laterites of the Guzerat nummulitics must, in all probability, have been formed of volcanic

detritus, washed down into the sea. They are only found amongst the very lowest tertiary beds, immediately above the traps, so that, as already suggested, they may have been contemporaneous with the high-level laterites. They are absolutely undistinguishable from the laterites of the Deccan. It is manifest that, whatever objection there may be to the acceptance of the view that the high-level laterites are formed from volcanic detritus, rearranged by water, it is certain that they may have been thus formed, and that the hypothesis involves no radical impossibility, because it is clear that the Guzerat laterites have originated in this manner.

There is, however, another objection to the hypothesis proposed, and it is at least as serious as the equal distribution of the iron. This is, that if laterite be formed from volcanic ashes, rearranged by water, why are no laterite beds found interstratified with the traps? It is unreasonable to suppose that loose materials were only washed down into the hollows and lower portions of the country after the close of the volcanic period, and not in the intervals between the lava flows. It is probable that the beds of bole, interstratified with the traps, are due to a similar process to that suggested for the origin of high-level laterite, but they are of comparatively small thickness or extent. Some of them, however, are highly ferruginous.

It will thus be seen that the suggestion above made, of the laterite being due to loose ash, rearranged by water, in the hollows left at the close of the volcanic outbursts, whilst satisfactorily explaining the mode of occurrence in a comparatively thin bed over wide areas, the absence of siliceous minerals, and the occasional intermixture of sand and pebbles, and whilst it is proved to be a possible theory by the fact that certain laterite beds must have been thus formed, fails to account, in an equally clear manner, for the universal distribution of so large a percentage of iron, or for the absence of lateritic beds interstratified with the traps, although these may be represented by the bands of red bole.

If the deposition of a thick bed of highly ferruginous clay be explained, the conversion of this clay into laterite appears to be due to the segregation of the iron either in a pisolitic form or as a cement binding the clay together. If the iron existed originally as magnetite, it has been peroxidized, and the peroxide has become more or less hydrated, the latter change taking place chiefly after exposure to the atmosphere. The pipes are not easily explained, nor is it at all clear why they are sometimes present and sometimes absent. They have been referred to the segregation of the iron in a tubular form and to the percolation of water, but they occasionally traverse parts of the rock which are not highly ferruginous, and in which they are not lined with

limonite; and although water may easily increase the size of the tube through which it passes, it is powerless to originate a channel, through solid rock, by percolation alone. The depth to which the tubes extend[1] appears too great to render it probable that they are due to roots of plants;[2] but, if once formed in this way, they might easily be kept open, and lined with a ferruginous glaze by the percolation of water.

When the formation of laterite beds has once been accounted for, the apparent change of lower beds into the laterite is evidently due to the decomposition of the underlying formation, and the infiltration of iron.

Beds at a lower level have, in all probability, been formed from the debris of the high-level laterite. It must be recollected that, in a formation like laterite, in which iron is irregularly distributed, the harder and heavier fragments, containing the greater portion of the iron, will be redeposited at no great distance by any transporting agency—as, for instance, rain-wash,—while the lighter and softer clays will be carried further. The highly ferruginous deposit, thus formed at a low level, would begin, as usual, to impregnate the decomposing rocks beneath it with iron, and to convert them into laterite.

Origin of low-level laterite.—This brings us to the subject of low-level laterite, as it appears along both coasts. It has already been explained that the rock forms a slope, with a very gentle inclination towards the sea; that it is clearly of detrital origin, and that it rests indifferently on various older rocks, metamorphic, gneiss, trap, or sandstone of various ages. Occasionally, as at Ratnagiri and near Cochin, sedimentary beds occur at the base of the laterite, and on the eastern coast laterite and gravel are interstratified, or pass into each other.

Some evidence will be given in the next chapter to shew that the slope on which the low-level laterite rests is, probably, a plane of marine denudation, formed when the coast lands were slowly emerging from the sea. The origin of the low-level laterite is, therefore, much more easily explained than that of the high-level formation. It may have been formed in places, as in the Konkan, south of Bombay, from the detritus of the high-level laterite; but one great difficulty in accounting for the origin of the latter—the presence of iron in large quantities—is easily explained, in the case of the low-level laterite, by the abundance of magnetic and specular iron sand, derived from the Deccan traps and the metamorphic rocks. The process by which an argillaceous deposit, rich in iron, is converted into laterite, must, of course, be the same as in the case of the high-level variety,

[1] Captain Newbold mentions one 30 feet in length at Bidar.

[2] There is a remarkable structural resemblance between some recent estuarine muds near Rangoon and laterite. In the mud, the tubes are due to roots, which decompose, and leave cylindrical pipes.

and the same effects have been produced by decomposition and infiltration of iron on the underlying rocks. The pisolitic nodules of brown hæmatite or limonite, so common in the low-level laterite and in various ancient alluvial deposits, probably derive their iron from the magnetite and specular iron sand.

There is one point on which a few words must be said, and that is the enquiry whether the low-level laterite is a marine formation. *A priori*, it would appear improbable that a marine formation should be deposited during the process by which a plane of marine denudation is elevated above the sea. On the other hand, the frequent occurrence of pebbles, often of large size, in the laterites of the east coast appears due to the action of the waves, especially where, as around isolated hills, which may originally have been islands, in Orissa, a mass of well-rounded shingle, in every way resembling a beach, is found cemented together by laterite. The absence of marine fossils may be due to their having been obliterated by the forces which produced the peculiar concretionary structure of the rock.

There are, however, two circumstances which appear to militate strongly against considering the laterite a marine formation. One of these is its remarkable thinness; throughout the east coast, so far as is known, it rarely exceeds 20 feet in depth; and the other is the very frequent occurrence in the Madras country of palæolithic implements embedded in the rock. Some of these might have been dropped into the sea from canoes, but it is incredible that the men who used the stones should have lost them in the sea in such numbers as would account for their present abundance.

On the whole, it appears most probable that the low-level laterite is a subaërial deposit, due however, in many cases, to the rearrangement of marine gravels and sands by rain and streams. All rain- and stream action would tend to carry away the lighter sand and clay, and to leave behind the heavy iron sand; and to this may be due the concentration of the ferruginous element.

Age.—The presence of palæolithic human implements in the Madras laterite proves that the rock is of post-tertiary origin. The implements[1] found are chiefly of quartzite, and have evidently been fashioned from pebbles, derived originally from the rocks of the transition or Vindhyan series. It is probable that the laterite of the west coast may be of about the same age as that near the eastern shore of the Peninsula.

[1] For descriptions and figures, see Foote; Mad. Jour. Lit. Sci., October 1866, Ser. III, Pt. 2, p. 1; also Q. J. G. S., 1868, p. 484. One form is the same as that represented on Plate XXI of the present work, fig. 1.

Despite the geologically recent origin of the low-level laterite, the considerable amount of denudation which it has undergone shews that it is, in part at least, a formation of ancient date, counting by years. It has already been mentioned that, on the western coast, the plateau near the sea has been cut through by streams to a great depth, and the underlying trap exposed, and that farther inland, at a higher level, only a few caps of the low-level laterite remain. On the eastern coast, which, owing to the large amount of deposits brought down by rivers, is protected from the action of the sea, the laterite has undergone less denudation, in consequence of its being frequently covered by later alluvial deposits, but still, away from the coast, it has been removed by atmospheric action over large areas. It is probable that the land rose very slowly from the sea, the laterite forming on the raised slope, *pari passu* with the elevation, and that, consequently, the farther inland the rock, the older its date, and the longer the period during which it has undergone denudation from atmospheric agencies. But the deep ravines cut by the streams close to the western coast, near Ratnagiri, mark the lapse of a considerable period of time since the low-level laterite was first consolidated, and a curious piece of evidence of the same kind has been recorded by Mr. Foote[1] in the neighbourhood of Madras.

Between two villages called Amerumbode and Maderapaucum, east of Sattavedu, and about 30 miles north-west by north of Madras, are some stone circles, made of blocks of the laterite, in which, in the immediate neighbourhood, palæolithic implements are found in abundance. The stone circles are known in the country as "Karambar rings," and precisely similar rings of stone are found in many parts of India, associated with various other rude stone buildings, such as kistvaens and cromlechs. That these stone circles are of much later date than the palæolithic implements is evident—first, because the circles are, in the particular case near Madras, constructed of rock in which the implements are embedded; secondly, because iron implements, which mark a far more advanced stage of human progress, have been repeatedly found within the enclosures; but, nevertheless, the stone circles themselves must be the work of a very ancient period, for all record of their construction, or even of the people who built them, has passed away. It will be shewn in the next chapter that the palæolithic age of India is, probably, of great antiquity, man having been, in all probability, contemporaneous with many animals now extinct, or replaced by different forms.

[1] Mem. G. S. I., X, p. 47.

CHAPTER XVI.

PENINSULAR AREA (THE INDO-GANGETIC PLAIN INCLUDED).

POST-TERTIARY AND RECENT FORMATIONS.

Extent — Distinction from tertiary beds — Relations to later tertiary rocks in Himalaya, Punjab, and Sind — Evidence of glacial epoch — Fauna and flora of Indian mountains — Post-tertiary changes of level in the Indian Peninsula — Hypothetical marine origin of Sahyádri scarp — Depression of land in the deltas of the Indus and Ganges — Lonar Lake — Various forms of post-tertiary deposits — Cave deposits — Kankar — — Older river gravels and clays — Alluvial plains of Narbada, Tapti, &c. — Old alluvium of Narbada — Palæontology — Fluviatile origin of Narbada alluvium — Tapti and Purna alluvial plains — Older alluvial deposits of Godávari — Krishna valley.

Extent.—Although the post-tertiary (post pliocene or quaternary) and recent formations of India occupy an immense area, their geological interest and importance are comparatively small. They form the wide plains of the Indus, Ganges, and Brahmaputra, and cover large tracts of country south of the Gangetic, and east of the Indus plain. No older formation is exposed throughout the greater portion of the belt of alluvial low land fringing the eastern coast of the Peninsula, and sub-recent accumulations occupy a large area in Guzerat and in some other districts near the western coast. Large deposits in the valleys of the Peninsular rivers and upon the fertile plains of the interior are also of recent or sub-recent origin.

Distinction from tertiary beds.—In India it is very difficult to draw a clear and distinct line between tertiary and post-tertiary formations. The limit of the two in Europe coincides with the glacial epoch, but as no physical trace of this cold period has hitherto been detected in Peninsular India, the distinction between the pliocene tertiary formations and the post-pliocene beds is less easily defined. Practically, no difficulty has hitherto arisen, because the tertiary beds of the Peninsula are comparatively unimportant, and those which occur belong apparently to the older or middle tertiaries, and not to the newer beds, so that there is a marked break between the tertiary and post-tertiary deposits; but some doubt attaches to the relative position of the most recent rocks in Kattywar. Hitherto, throughout Peninsular India, except in the neighbourhood of the sea coast, all post-tertiary deposits known are

of fresh-water origin,[1] and all the unconsolidated and undisturbed deposits of the river valleys are classed in this division. Amongst the older valley deposits, as in the post-pliocene rocks of Europe, bones of extinct mammals are found together with recent forms of fresh-water and terrestrial mollusca, whilst the newer gravels, sand and clay contain only the remains of mammalian species identical with those now inhabiting the country. There is some possibility that, amongst the fossiliferous gravels of the Indian river valleys, beds of older age than post-pliocene may occur, but hitherto no fossils of undoubted tertiary date have been discovered in the superficial deposits, although some forms differ so widely from living species as to suggest the existence of older beds. The works of man have now been found in two instances in Indian post-pliocene beds, but no human remains have hitherto been detected in older formations. These remarks, however, apply solely to India; in Burma, as will be shewn hereafter, tertiary mammals are found in the beds of the river valleys.

Relations to tertiaries of Himalaya, Punjab, and Sind.—South of the great Indo-Gangetic plain, the post-tertiary deposits rest upon old formations, all of pre-tertiary date, but to the north and west of the plain, at the base of the Himalayas, and on the flanks of the hill ranges in Sind and the Punjab, as well as throughout the valley of Assam, later tertiary rocks immediately underlie the post-tertiary beds. There is, in these cases, a marked distinction between the two, the pliocene tertiaries of the Siwalik formation being greatly disturbed, and evidently older than the last great changes in the relative levels of the Himalayan region, Afghanistan and Baluchistan, whilst the modern alluvial deposits preserve their original horizontality. But even in this case the difficulty, already noticed, of drawing a definite line between the tertiary and the later beds is exemplified, for, in the uppermost beds of the Siwalik series, some mammalia are represented, of which the bones are also found in the older valley deposits of the Peninsula. The difficulty increases on passing into the Irawadi valley in Burma, where beds, apparently representing the disturbed Siwalik rocks and containing the same species of mammals, are found horizontal and unconsolidated immediately beneath the sub-recent valley deposits.

Evidence of glacial epoch.—It has already been stated that there is, in Peninsular India, so far as is known, no physical evidence of a geologically recent cold epoch, and some European geologists appear to

[1] It will be shown presently that the opinion held by some observers, that the older alluvial deposits of the Gangetic plain are marine, is unsupported by evidence.

doubt whether India was affected by the glacial period. There is in the Himalayas abundant and unmistakable evidence of a great extension of the glaciers at no very distant geological date, ancient moraines being found in many valleys of Sikkim and Eastern Nepal at elevations of between 7,000 and 8,000 feet,[1] and distinct traces of glacial action exist in valleys the lowest portion of which is not now more than 5,000 feet[2] above the sea. Moraines have been noticed by Colonel Godwin-Austen[3] farther east in the Nága hills, south of the Assam valley, as low as 5,000 feet; in the Western Himalayas, perched blocks are found 3,000 feet above the sea,[4] and very large erratics have recently been noticed in the Upper Punjab at much lower elevations.[5] It has, however, been suggested that the Himalayas, although they are still the loftiest mountains in the world, may have been depressed 8,000 feet since the period when the glaciers reached their maximum extension,[6] and the supposed erratics of the Western Himalaya and Punjab have been referred to river action.[7] The explanation in both cases appears quite inadequate by itself, unless the temperature was much lower than at present; still, it is of much importance to ascertain whether any collateral evidence is procurable of a cold period in India in later tertiary or post-tertiary times, it being remembered that a general refrigeration of the earth's surface, sufficient to produce an arctic climate in Central Europe, would not diminish the temperature of the Indian Peninsula below the average of the temperate zone at the present time.

It is true that no proof of the former existence of glaciers on the hills of Southern India has ever been detected, but this is important so far as negative evidence can be trusted, because it accords with the general absence, throughout the Peninsula of India, of any indication of depression on a large scale in recent geological times, and with the probability of the peninsular area having lately undergone a slow elevatory movement. The fact, however, that the hills of Southern India are probably higher, certainly not lower, than they were in late geological times, lends much force to the argument, derived from the animals and plants inhabiting them, in favour of a lower temperature having existed at a comparatively recent geological period.

[1] Hooker's Himalayan Journals, II, p. 7, &c.
[2] J. A. S. B., 1871, XL, Pt. 2, p. 393.
[3] J. A. S. B., 1875, XLIV, Pt. 2, p. 209.
[4] Mem. G. S. I., III, Pt. 2, p. 155.
[5] By Messrs. Theobald and Wynne, Rec. G. S. I., VII, p. 86, X, pp. 123, 140; Mem. G. S. I., XIV, p. 116.
[6] Mem. G. S. I., III, Pt. 2, p. 156.
[7] J. A. S. B., 1877, XLVI, Pt. 2, p. 1.

Fauna and flora of Indian mountains.—This argument is, briefly, the following. On several isolated hill ranges, such as the Nilgiri (Neilgherry), Animalé (Animullay), Shivarai (Shevroys), and other isolated plateaus in Southern India, and on the mountains of Ceylon, there is found a temperate fauna and flora, which does not exist in the low plains of Southern India, but which is closely allied to the temperate fauna and flora of the Himalayas, the Assam range (Garo, Khási, and Nágá hills), the mountains of the Malay Peninsula and Java. Even on isolated peaks, such as Parasnáth, 4,500 feet high, in Behar, and on Mount Abu in the Arvali (Aravelli) range, Rajpútána, several Himalayan plants exist. It would take up too much space to enter into details: the occurrence of a Himalayan plant like *Rhododendron arboreum*, and of a Himalayan mammal like *Martes flavigula* on both the Nilgiris and Ceylon mountains will serve as an example of a considerable number of less easily recognised species. In some cases there is a closer resemblance between the temperate forms found on the peninsular hills and those on the Assam range[1] than between the former and Himalayan species, but there are also connections between the Himalayan and peninsular temperate regions which do not extend to the eastern hills. The most remarkable of these is the occurrence on the Nilgiri and Animalé ranges and on some hills further south of a species of wild goat, *Capra hylocrius*, belonging to a sub-genus (*Hemitragus*), of which the only other known species, *C. jemlaica*, inhabits the temperate region of the Himalayas from Kashmir to Bhútán. This case is remarkable, because the only other wild goat found completely outside the Palæarctic region is another isolated form on the mountains of Abyssinia.[2]

The range in elevation of the temperate fauna and flora of the Oriental region in general appears to depend more on humidity than temperature, many of the forms, which, in the Indian hills, are peculiar to the higher ranges, being found represented by allied species at lower elevations in the damp Malay Peninsula and Archipelago, and some of

[1] Only one species of plant, however, is mentioned by Hooker and Thomson (Introductory Essay to the Flora Indica, p. 238) as being found both in the Khási hills and Nilgiris, but not in the Himalayas. One land shell at least, *Bulimus nilagaricus*, has the same distribution, and the genus *Streptaxis* is found in Burma, the Khási hills, and the Southern Indian ranges, but not in the Himalaya west of Bhútán. Several other instances might be quoted.

[2] A still more extraordinary case, if confirmed, would be the occurrence of a snake belonging to the Palæarctic genus *Halys* on the hills of Southern India, but the affinities of *Trigonocephalus ellioti* are still doubtful, the species not having been discovered by later observers. The importance of the occurrence of a wild goat on the hills of Southern India is slightly diminished by Mr. Lydekker's discovery of extinct species in the Siwaliks and in the upper tertiary beds of Perim Island.

the hill forms being even found in the damp forests of the Malabar coast. The animals inhabiting the Peninsular and Ceylonese hills belong, for the most part, to species distinct from those found in the Himalaya and Assam ranges, &c.; in some cases even genera are peculiar to the hills of Ceylon and Southern India, and one family of snakes is unrepresented elsewhere. There are, however, numerous plants and a few animals inhabiting the hills of Southern India and Ceylon which are identical with Himalayan and Assamese hill forms, but which are unknown throughout the plains of India.

That a great portion of the temperate fauna and flora of the Southern Indian hills has inhabited the country from a much more distant epoch than the glacial period may be considered as almost certain, there being so many peculiar forms. It is possible that the species common to Ceylon, the Nilgiris, and the Himalayas may have migrated at a time when the country was damper, without the temperature being lower, but it is difficult to understand how the plains of India can have enjoyed a damper climate without either depression, which would have caused a large portion of the country to be covered by sea, a diminished temperature which would check evaporation, or a change in the prevailing winds. The depression may have taken place, but the migration of animals and plants from the Himalayas to Ceylon would have been prevented, not aided, by the southern area being isolated by sea, so that it may be safely inferred that the period of migration and the period of depression were not contemporaneous. A change in the prevailing winds is improbable so long as the present distribution of land and water exists, and the only remaining theory to account for the existence of the same species of animals and plants on the Himalayas and the hills of Southern India is depression of temperature.[1]

Post-tertiary changes of level in the Indian Peninsula.—In the preceding discussion of changes probably caused by the glacial period, and also in the chapter on laterite, a recent rise of the Indian Peninsula was mentioned. It will be useful, before describing the post-tertiary formations, to state the evidence on which the belief in a recent rise of land is founded.

[1] The above is a meagre and condensed account of a very interesting subject, which requires further enquiry. One possible objection may be answered at once. It is true that many of the temperate damp-loving forms of the Nilgiris and Ceylon hills are forest forms, and it may be urged that they might have migrated when the plains of India were covered with forest. But, judging from what remains of the forest on the plains of the Carnatic, Deccan, Central Provinces, &c., the flora even when the whole was forest differed so widely from that of the hills, that it is improbable that any general diffusion of hill species could have taken place without a change of climate.

In a subsequent chapter, reference will be made to the probable influence of the glacial epoch on the Siwalik mammalian fauna.

In the chapters of this work relating to the Himalaya, the Punjab, and Sind, it will be shewn that great disturbances and important changes have taken place since the close of the pliocene epoch. In all the countries mentioned, rocks containing the remains of later tertiary mammalia are found dipping at high angles and not unfrequently vertical, and although, in the Himalayas, there is evidence of great disturbance at an earlier period, it appears probable that the older tertiary rocks in Sind have been chiefly, if not entirely, upheaved since the deposition of the pliocene beds. In Baluchistan also pliocene strata are found greatly disturbed, but the direction of the folds into which the strata appear to have been thrown is at right angles to the strike of the anticlinal and synclinal axes in Sind.

There is no clear evidence that any portion of the Peninsula of India was affected by the disturbances to which the elevation of the Himalayas and of the Sulemán and Khirthar ranges in the Punjab and Sind is due. But it is scarcely credible that, whilst such enormous changes were taking place in neighbouring areas, no alteration of level should have ensued in the Peninsula. In the sea to the south-west, the presence of the Maldive, Laccadive, and Chagos groups of atolls and coral reefs points to slow depression, and there is unmistakable proof of a recent sinking of the land on the Arabian coast near the mouth of the Persian Gulf.[1] On the coasts of India, except in the Gangetic delta, however, no distinct evidence of recent depression has been noticed,[2] whilst at several points contrary indications have been detected.

Commencing on the eastern coast of India, the first thing to be noticed is, that the low-level laterite is deposited on a gentle slope of older rocks, such as is formed by the sea, and known as a plane of marine denudation. It is true that this slope has been much broken up and denuded in places, so that the period of its elevation may be old, counting by years, but the fact that the laterite rests upon a surface of the older rocks, unaffected by subaërial action, shews that the period of elevation and the formation of the laterite were either contemporaneous, or separated by a brief interval of time, and the post-tertiary date of the laterite is proved by the presence of human implements.

Around some of the hills, also, as already noticed in the remarks on laterite, rounded pebbles, apparently belonging to an old sea beach, are found cemented by laterite. This is at an elevation of probably not less than 100 to 200 feet above the present sea-level. Nearer to the sea,

[1] Rec. G. S. I., V, p. 76.

[2] For instances of encroachment by the sea on the coast, see Newbold, Jour. R. A. S., VIII, pp. 250, 252, &c., and King and Foote, Mem. G. S. I., IV, p. (362). The destruction mentioned is, however, solely due, so far as is known, to the ordinary action of the waves, and no depression of land has been shewn to take place.

beds of marine or estuarine shells have been found both in Orissa and near Madras, at a height of several feet above the sea, and at a considerable distance inland. Further details of these beds will be given on a subsequent page. On the coast of Orissa, parallel ranges of sand-hills appear to mark old shore lines; the tide is said formerly to have come farther up the rivers[1] than it does now, whilst the Black Pagoda near Puri (Pooree), originally said to have been built on the sea-shore, is now more than a mile distant inland.[2] In the extreme south of India, near Ramnad, sandstones occur, some of which form Adam's Bridge between the Peninsula and Ceylon; and it is stated by Newbold[3] that these beds contain recent marine shells, and must have been raised from the sea at no distant date. It, however, remains to be seen whether the rocks are not of tertiary age, like the Cuddalore sandstones.

Passing onwards to the west coast, the low-level laterite is again found resting on a slope of the older rocks, and this slope again presents the characters of an ancient plane of marine denudation. The laterite in the Bombay Konkan, near the coast, appears to be raised to a greater height above the sea than on the opposite shore of the Peninsula; this may be due to the much greater destruction of the west coast by the sea, and to the circumstance that the newer laterite at the lowest level has been swept away; the force of the sea on this coast being increased by the strong south-west monsoon, whilst the defence afforded by river deposits on the east coast is in a great measure wanting on the western. But it is also probable that more elevation has taken place to the westward, and some further evidence to this effect will be mentioned, in reference to the alluvial deposits of the rivers Narbada and Tapti. At Bombay recent marine shells are found, forming the flat on which part of the city is built, several feet above high-water mark. In Kattywar, especially near Porbandar, dead oysters were found by Mr. Theobald in the creeks at several places far above the present range of the tide, and at Patan, barnacles and *serpulæ* were observed on the foundation of an old temple, now only wetted by the highest floods. In Sind, a number of oysters have been noticed attached to a low cliff at least 10 feet above high-water mark close to Cape Monze.[4] In the case of Kattywar and Sind, however, the elevation may be very recent, and these countries are beyond the true peninsular limits.

Hypothetical marine origin of Sahyadri scarp.—The escarpment of the Sahyádri range, a remarkable feature of the hills parallel

[1] Mem. G. S. I., I, p. 276.

[2] For many native traditions of a rise of land both on the Coromandel and Malabar coasts, see Newbold, Jour. R. A. S., VIII, p. 250, &c.

[3] l. c., p. 243.

[4] MS. reports; see also Rec. G. S. I., V, p. 111.

to the western coast of the Peninsula, has frequently been noticed as furnishing evidence of a rise of land. Throughout the trap country of the Bombay Presidency, the Western Gháts rise from the Konkan in an almost unbroken wall, varying in height from 2,000 to 4,000 feet, cut back in places by streams, projecting here and there into long promontories, but preserving throughout a singular resemblance to sea cliffs. This resemblance, however, ceases to a great extent to the southward, where the metamorphic rocks replace the horizontal basaltic traps. The escarpments of the Málwa plateau, north of the Narbada, and of the Deccan plateau south of Khándesh, although far inferior in elevation to the scarp of the Sahyádri, resemble the latter too closely in appearance to justify the assumption, without further evidence, that the cliffs of the Western Gháts are of marine origin. The parallelism of the Sahyádri escarpment to the sea-coast is suggestive of a connexion between the two, and this connexion is strengthened by the facts that a thickness of at least 4,000 feet of bedded trap has been removed from the surface of the Bombay Konkan, and that the plane of marine denudation already mentioned as supporting the low-level laterite extends in places nearly to the foot of the scarp. The circumstance that the hills of the Sahyádri are inhabited by certain fresh-water mollusca belonging to the genus *Cremnoconchus*, which is unknown elsewhere, and which is so closely allied to Indian forms of the littoral marine genus *Littorina* as to render it probable that both are descended from the same ancestors, also tends to strengthen the view that the Sahyádri mountains were formerly washed by the sea. But it is certain that great denudation has taken place since the scarp was a sea cliff, and it is far from improbable, even if the sea once extended to the base of the Western Gháts, that the epoch belonged rather to tertiary than post-tertiary times. It is also possible that the isolation of the different hill ranges of Southern India, such as the Shivarai, and the denudation of the Pálghát Gap south of the Nilgiri plateau, are due in part to ancient marine action of the same date as the formation of the Sahyádri escarpment. In this case, as in so many others connected with Indian geology, all that is now possible is to suggest probable interpretations of phenomena, and to leave them for future exploration to confirm or contradict.

Depression of land in deltas of Indus and Ganges.—But whilst throughout the rock area of the Indian Peninsula there are numerous proofs of an elevation of land during late geological epochs, the evidence of depression is equally marked in the delta of the Ganges, and probably in that of the Indus. The details of the Calcutta bore-hole will be given in a subsequent page, and they alone suffice to prove that the ground in the neighbourhood of the Hooghly must have

been depressed at least 480 feet in comparatively recent times. There are also other circumstances connected with the physical geography of the delta which point to the probability of considerable sinking having taken place. In the delta of the Indus the evidence is less clear, and the only known cases of depression are those said to have coincided with the earthquakes of 1819 and 1845. Both east of the Indus delta, in Kattywar, and to the westward near Cape Monze in Sind, there is, as already noticed, evidence of a recent rise of land, and it is probable that the lower portion of the Indus plain, with the Ran of Cutch and other tracts in the neighbourhood, have only, in recent geological times, been converted into land, as will be shewn when describing the delta.

Volcanic eruptions in Bay of Bengal.—It must not be forgotten that the great belt of volcanoes which extends throughout the Malay Islands, Java, Sumatra, &c., is supposed to terminate in Barren Island in the eastern portion of the Bay of Bengal, at a considerable distance from the coast of the Indian Peninsula. The belt of volcanoes should perhaps rather be considered as terminating at Narcondam than at Barren Island. By many writers it has been suggested that the mud volcanoes of Cheduba and Rámri on the coast of Arakan are a northern continuation of the Malay volcanic chain, but this is improbable, despite various accounts of eruptions and upheaval of land, because there is no known connection between the so-called "mud-volcanoes" and true volcanic action.[1] A distinctly volcanic outburst, accompanied by showers of pumice and ashes, is said to have taken place in the sea off Pondicherry in 1756,[2] and to have formed a shoal which subsequently disappeared, but the description, as in the case of the Cheduba eruptions, contains some elements of doubt.

Lonar Lake.—This is, perhaps, the best place to notice a very curious crateriform lake[3] situated in the interior of the Indian Peninsula, near the village of Lonar, about 40 miles east by north of Jálna, in the northern part of the Nizam's territory, and about half way between Bombay and Nágpúr. The surrounding country for hundreds of miles consists entirely of Deccan trap; in this rock, at Lonar, there is a nearly circular hollow about 300 to 400 feet deep, and rather more than a mile in diameter, containing at the bottom a shallow lake of salt water without any outlet. This water deposits crystals of sesquicarbonate of soda according

[1] For a full account of these supposed eruptions, see Buist, Ed. New Phil. Jour., 1852, LII, p. 342. The mud-volcanoes of Rámri will be further noticed in the chapter on Burma.

[2] J. A. S. B., 1847 XVI, p. 499.

[3] Malcolmson, Trans. Geol. Soc., Ser. 2, V, p. 562; Newbold, Jour. Roy. As. Soc., IX, p. 40 (with this paper there is a fairly executed view of the lake); G. Smith, Mad. Jour. Lit. Sci., XVII, p. 1. See also Rec. G. S. I., Vol. I, p. 63, where other references are given.

to Malcolmson, who analysed them. The sides of the hollow to the north and north-east are absolutely level with the surrounding country, whilst in all other directions there is a raised rim, never exceeding 100 feet in height, and frequently only 40 or 50, composed of blocks of basalt, irregularly piled, and precisely similar to the rock exposed on the sides of the hollow. The dip of the surrounding traps is away from the hollow, but very low.

It is impossible to ascribe this hollow to any other cause than volcanic explosion; no such excavation could be produced by any known form of aqueous denudation, and the raised rim of loose blocks around the edge appears to preclude the idea of a simple depression. It is true that there is no sign of any eruption having accompanied the formation of the crater; no dyke can be traced in the surrounding rocks; no lava or scoriæ of later age than the Deccan trap period can be found in the neighbourhood. The raised rim is very small, and cannot contain a thousandth part of the rock ejected from the crater; but it is impossible to say how much was reduced to fine powder, scattered to a distance, or removed by denudation.

Assuming that this extraordinary hollow is due to volcanic explosions, the date of its origin still remains to be determined. That this is long posterior to the epoch of the Deccan traps is manifest; for the hollow appears to have been made in the present surface of the country, carved out by ages of denudation from the old cretaceous lava flows. To all appearance, the Lonar lake crater is of comparatively recent origin; and if so, it proves that in one isolated spot in India, a singularly violent explosive action must have taken place, unaccompanied by the eruption of melted rock. Nothing similar is known to occur elsewhere in the Indian Peninsula.

Various forms of post-tertiary deposits.—The following are the most important post-tertiary formations in Peninsular India, the newest being placed first. The Indo-Gangetic plain will be treated in the present chapter as a portion of the Peninsula.

1. Blown sand.
2. Soils, including black soil or regur.
3. Modern alluvial deposits of rivers and deltas.
4. Raised littoral accumulations of shells, sand, &c.
5. Alluvium of the Coromandel coast, Guzerat, Cutch, &c.
6. Coast laterite.
7. Older alluvial river deposits.
   Alluvium of Indo-Gangetic plain.
   Narbada gravels.
   Godávari gravels and other older river deposits.
8. Cave deposits.

It will, however, not be convenient to treat of these deposits precisely in the order mentioned, which coincides, so far as is known, with the probable geological succession of the various beds. The newer and the older forms of alluvial deposits are in many parts of India so closely connected with each other, and so difficult to distinguish, that they must be discussed together. The coast laterite has been already described in the last chapter.

Cave deposits.—There is only one locality in the Indian Peninsula at which mammaliferous cave deposits have been detected. This is at a place called Billa Súrgám,[1] a few miles north of Bánaganpilí, in the Karnúl district. The caves are in limestone belonging to the Karnúl transition series; the interior of the hollows examined is encrusted with stalagmite, and, beneath a floor of this substance, a red indurated marl is found, abounding in bones of mammals, large and small. The bones of the smaller animals are said to occur in large quantities. A collection made by Captain Newbold, who discovered the caves, was presented to the Asiatic Society of Bengal, but no description of the bones was ever published, nor can the specimens be found at present. A larger and more perfect collection was retained by Captain Newbold for examination in Europe, but no account of it appears ever to have been published. During the period of more than thirty years which has elapsed since attention was called to the locality by Captain Newbold, the spot appears to have been forgotten, and we are still ignorant of the value of the mammalian remains preserved.[2]

Kankar (kunkur).—Before proceeding further, a few words are requisite in explanation of a word which it will be found necessary to use occasionally in the following pages. To Anglo-Indians it is quite unnecessary to explain the meaning of the term *kankar*, but the explanation may be of some use to European students. The original signification of the word is gravel, the term being applied to any small fragments of rock, whether rounded or not. By Anglo-Indians, however, the name has been especially used for concretionary carbonate of lime, usually occurring in nodules, in the alluvial deposits of the country, and especially in the older of these formations. The commonest form consists of small nodules of irregular shape, from half an inch to three or four inches in diameter, and composed within of tolerably compact carbonate of lime and externally of a

[1] A description by Captain Newbold, the discoverer, is given; J. A. S. B., XIII, 1844, p. 610.

[2] It is proposed by the Geological Survey to re-examine the locality as soon as possible.

mixture of carbonate of lime and clay.[1] The more massive forms are a variety of calcareous tufa, which sometimes forms thick beds in the alluvium, and frequently fills cracks in the alluvial deposits, or in older rocks.[2] In the beds of streams immense masses of calcareous tufa are often found forming the matrix of a conglomerate, of which the pebbles are derived from the rocks brought down by the stream. There can be no doubt that the kankar nodules, calcareous beds, and veins are all deposited from water containing in solution carbonate of lime, derived either from the older rocks of various kinds, or else from fragments of limestone and other calcareous formations contained in the alluvium.

Older river gravels and clays.—The older alluvial deposits of the Indian rivers comprise a large portion of the enormously thick clays, gravels, &c., of the great plains of Northern India, and they are also well represented in the valleys of the Peninsula. Leaving for the moment the description of the Indo-Gangetic plain, the various older alluvial deposits of the peninsular rivers deserve notice, both on account of the area occupied and of the organic remains they have yielded. The rivers of the Peninsula may be divided into two groups; the first, comprising the Narbada and Tapti, which flow westward, draining the central portion of the peninsula, and the second including the Máhánadi, Godávari, Krishna, Pennar, Káveri, and several minor streams flowing eastward into the Bay of Bengal. A third group might be composed of the southern affluents of the Ganges, the Chambal, Son, &c., whilst some streams of Rajpútána and Guzerat, of which the most important are the Máhi and Lúni might be classed with the Narbada and Tapti, but none, except the two last named, are known to contain old alluvial deposits of any importance.

[1] The following analyses will give a fair idea of the usual composition of nodular kankar:—

	1		2	3	4		5	6	7	8	9
Carbonate of lime ...	72·	...	72·	56·94	78·5	...	54·	65·4	66·3	57·18	79·33
Carbonate of magnesia	0·4	...	1·30	1·72	2·	...	...	...	...	...	...
Silica	15·2	Oxide of iron . .	·70	1·67	2·	Oxide of iron and alumina . .	2·7	1·9	2·	10·32	6·73
Water	1·4	Clay .	22·	30·	10·50	Water and organic matter . . .	2·7	2·3	4·5		
Oxide of iron and alumina . . .	11·0	Sand . .	2·	9·67	7·	Insoluble . .	40·6	30·4	27·2	32·50	13·94

1, Ghazipur, Prinsep, Gleanings in Science, III, p. 278; 2, 3, 4, Rániganj, Dejoux, Rec. G. S. I., VII, p. 123; 5, Barmuri; 6, Ramnagar; 7, Sanktoria, all near Rániganj, Tween, ibid.; 8, 9, Sahâranpur, Thomson, Rurki Treatise, Civil Engineering, I, p. 115.

[2] See the account by Captain E. Smith of the kankar in the Jumna alluvium, J. A. S. B., II, p. 622; also Newbold, J. R. A. S., VIII, p. 258.

Alluvial plains of Narbada, Tapti, &c.—In dealing with the two groups first named, one striking peculiarity deserves notice. Extensive alluvial plains, composed of clays and gravels, exist in the valleys of the Narbada and Tapti. In the Narbada valley, the principal plain extends from a little east of Jabalpur to Harda, a distance of more than 200 miles, and varies in breadth from 12 miles to 35. There is a smaller plain further down the river extending for about 80 miles from Barwai to the Harin Pal, south of Bágh, but it is comparatively ill-marked, the alluvial deposits are much less deep so far as is known, and no mammalian remains have been found in them. In the Tapti valley, there is a large plain in Khándesh, extending east and west for about 150 miles, and terminating to the eastward close to Burhánpúr. This plain lies chiefly to the north of the river, and is probably in places as much as 30 miles wide, but its limits have not been accurately determined. It appears to be connected by a narrow alluvial belt to the south-east with the plain of the Púrna,[1] a tributary of the Tapti, draining a great portion of Berar. The Púrna plain is at a higher level than Khándesh, and is about 100 miles long, and in places 40 miles broad, its eastern extremity being near Amráoti (Omrawattee), so that the whole length of the combined Tapti and Púrna plains is about 240 miles. The Tapti plain and both the Narbada plains are closed on the west by rocky and hilly country, through which the river has cut a channel with a rapid descent, and in the Narbada, as will be explained presently, it is ascertained that the upper alluvial basin extends to a considerable depth beneath the level of the river bed at the point of exit, so that the alluvial plain lies in a great rock basin.

In the valleys of the eastward-flowing rivers, such as the Godávari, Krishna and Káveri, there are no such broad and well-defined alluvial plains as in the drainage areas of the Tapti and Narbada. There are numerous extensive alluvial flats in many places, but they are far inferior in extent to the Narbada and Tapti plains, and they appear to be chiefly due to the river having worn a broad valley through soft, or easily disintegrated rocks. This is especially the case on the Godávari and its tributaries, the alluvial portions of the river valley being in the Gondwána series, or else in the Deccan traps, whilst the river traverses rocky gorges through the metamorphic rocks forming the various "barriers," at the places where the valley leaves the softer formations. On the Narbada and Tapti it is otherwise; the rocks underlying the alluvial areas, so far as they are known, are of the same kind as those cut through by the rivers at their exit from the plains. It is not improbable that the

[1] This is not quite certain, however, the ground not having been properly surveyed. There is a considerable amount of rock exposed in the rivers between the two plains, but the fall from one to the other cannot be much more than 100 feet to judge by the railway levels.

formation of these well-defined plains in the Narbada and Tapti valleys, and the absence of similar flats on the Godávari and Krishna, may be due to the rise of the Indian Peninsula in post-tertiary times having been, as already suggested, greater or more rapid to the westward than to the eastward.

Old alluvium of Narbada.—Partly in consequence of mammalian bones having been discovered in considerable quantities, and partly because the geology of the neighbouring country is of so much interest and variety as to have attracted the notice of many geologists, the alluvial deposits of the Narbada valley have received far more attention than similar formations on the banks of the other Indian rivers.[1] The great plain already mentioned as extending from Jabalpur to Harda is chiefly composed of a stiff, reddish, brownish or yellowish clay, with numerous bands of sand and gravel intercalated. Kankar abounds throughout the deposit, and pisolitic iron granules are of frequent occurrence in the argillaceous beds. Occasionally pebbles and sand are found cemented together by carbonate of lime so as to form a hard compact conglomerate. This rock is especially developed at the base of the alluvial deposits, and, not only in the Narbada, but in many other river valleys, it is often found forming a coating to the underlying rock. The clay is frequently quite devoid of stratification, but it appears never to attain any great thickness without sandy layers intervening. The river, in many places, cuts through the clays, sands and gravels to the underlying rock (usually belonging to the transition series), and the section of old alluvial deposits on the banks of the stream never greatly exceeds 100 feet in depth, this being about the usual difference in elevation between the bed of the Narbada and the general surface of the alluvial plain in the neighbourhood of the river. But in a boring which was made at Súkakheri, north of Mopáni and south of the Gádarwára station on the Great Indian Peninsula Railway, a depth of 491 feet was attained, without the base of the alluvial deposits being reached: another bore-hole was made through alluvial beds close to Gádarwára station to a depth of 251 feet. These bores were made for the purpose of ascertaining if the coal-bearing rocks of Mopáni extend to the northward; and the great depth of the alluvial deposits was quite unexpected. Throughout the thickness of nearly 500 feet, no change of importance was detected in the alluvial formations. By far the greater portion of the beds traversed consisted of clay with calcareous and ferruginous grains, sand and pebbles being found occasionally throughout. The bottom of the bore-hole was in lateritic gravel, and it is possible that rock was not far distant.

[1] For descriptions of the Narbada alluvial deposits, see Theobald, Mem. G. S. I., II, pp. 279-298. See also Mem. G. S. I., VI, pp. (227)-(232); Rec. G. S. I., VI, p. 49, VIII, p. 66.

The evidence thus obtained of the depth to which the alluvial deposits of the Narbada valley extend proves that they fill a rock basin, for the bed of the Narbada river, at the point where it leaves the alluvial plain near Hindia and commences to run through the rocky channel which extends to Barwai, is not more than 200 feet below the level of the surface at Gádarwára and Súkakheri, and the valley is surrounded by higher rocky ground in every other direction. A slight prolongation of the alluvial basin to the south-west in the direction of Harda, the prevalence of alluvium in parts of Nimar, and the circumstance that there is a great break by which the railway traverses the Sátpúra range, immediately east of Asirgarh, may indicate that the upper Narbada formerly joined the Tapti in Khándesh,[1] and that the lower valley of the former river as it now exists is due to changes of level in the later post-tertiary period.

The surface of the Narbada alluvium is undulating, and evidently denuded by the action of rain and streams. There is a slight slope of the surface to the westward throughout the plain; the elevation of the railway station at Harda, at the western extremity of the alluvial tract, being 947 feet above the sea, whilst Sohágpúr station is 1,103 feet, Narsingpúr 1,185, and Jabalpur, which, however, is on rock a little above the plain, 1,351. The fall of the surface in 200 miles is probably about 300 feet.

Palæontology.—Different views have been put forward as to the marine, lacustrine, or fluviatile origin of the Narbada alluvial deposits, but, before considering these, it will be well to give a list of the organic remains hitherto identified. They consist of bones and shells, and the following species have been determined[2] :—

VERTEBRATA.

MAMMALIA—
- Man (stone weapons).
- *Felis*, sp.
- *Ursus namadicus*, Pl. XX, fig. 6, molars.
- *Mus*, sp.
- *Elephas namadicus*, Pl. XX, fig. 5, molar, 8, skull.
- *E.* (*Stegodon*) *insignis*.
- *Rhinoceros namadicus*, Pl. XX, fig. 9, astragalus.
- *Equus namadicus*, Pl. XX, fig. 4, molars.
- *Hippopotamus* (*Hexaprotodon*) *namadicus*, Pl. XX, fig. 2, mandible.
- *H.* (*Tetraprotodon*) *palæindicus*, Pl. XX, fig. 7, molar.
- *Bos namadicus*, Pl. XX, fig. 3, frontlet.
- *B.* (*Bubalus*) *palæindicus*, Pl. XX, fig. 1, skull.
- *Cervus* (*Rucervus*) *namadicus*.

REPTILIA—
- *Emys* (*Pangshura*) *tectum*.
- *E.* (*Batagur*) conf. *dhongoka*.
- *Trionyx*, conf. *gangeticus*.
- *Crocodilus*, sp.

[1] The greatest elevation on the G. I. P. Railway, between the Narbada and Tapti valley, is 1,245 feet above the sea, or only 300 feet above Harda in the Narbada alluvial plain.

[2] Mem. G. S. I., II, pp. 284, 295 (these lists are not quite accurate); Rec. G. S. I., II, p. 36; VI, p. 54; IX, p. 88. The last is a list of the mammalia by Mr. Lydekker. See also Falconer, Pal. Mem., I, p. 21; II, p. 577, &c.

Note.—The species thus marked* are not determined with certainty, no specimens having been preserved in the Geological Museum.

MOLLUSCA.

GASTEROPODA—
Melania tuberculata.
Paludina bengalensis.
P. dissimilis.
* *Bythinia cerameopoma.*
* *B. pulchella.*
Bulimus insularis.
* *Lymnea acuminata.*
Planorbis exustus.
* *P. compressus ?*

LAMELLIBRANCHIATA—
Unio corrugatus ? var.
U. indicus.
U. sp. near *U. shurtleffianus.*
U. marginalis.
Corbicula, sp., near *C. striatella.*

The only trace of man hitherto found in these deposits consists of a chipped stone scraper or hatchet [1] (Pl. XXI, fig. 1), discovered by Mr. Hacket *in situ* near the village of Bhutra, 8 miles north of Gádarwára. The material is Vindhyan quartzite, and the form similar to that of some of the implements found in the lateritic deposits of Southern India, and in the post-pliocene formations of Europe.

The mammalian forms related to existing Indian species are *Elephas namadicus*, allied to the existing Indian elephant, *Bos palæindicus*, very close to the living Indian wild buffalo, and *Cervus namadicus*, a near relation to the Bárasingha (*Cervus duvaucelii*). On the other hand, *Elephas insignis* and *Hippopotamus namadicus* belong to extinct sub-genera, the first being common to the pliocene Siwalik rocks, and the latter replaced by a nearly allied species. *Hippopotamus palæindicus* and *Bos namadicus* are not nearly allied to any Indian living species; the first belongs to a genus now only found in Africa, whilst the second, although having some characters in common with the living wild cattle of India *Bos* (*Bibos*) *gaurus*, differs from the latter in many important particulars, and appears to be quite as closely connected with true taurine oxen belonging to the type of *Bos taurus*. *Bos namadicus*, indeed, cannot be classed in the sub-division *Bibos*. The relations of the remaining mammals are less distinctly made out, the specimens on which the species are founded being for the most part fragmentary.

The only reptile clearly identified is *Emys tectum*, which is considered identical with a living Indian form. It is very singular that only fragmentary remains of crocodiles occur, for they abound in the Siwalik rocks, and a species is common in the Narbada at the present day. The mollusca appear to be the same as species now living in the area, and all the commonest forms now known to occur in the river valley are represented,[2] except some minute species of land shells.

[1] Rec. G. S. I., VI, p. 49; two figures of the implement are given.

[2] The only exception of any importance is *Melania spinulosa*, but that is not by any means so generally distributed a form as *M. tuberculata*. The absence in the Narbada deposits of *Melania variabilis* and *M. spinulosa*, the latter of which is included in Mr. Theobald's lists of living Narbada species, Mem. G. S. I., II, p. 287, was noticed by Dr. Falconer, Q. J. G. S., 1865, p. 382, but it is extremely doubtful whether *M. variabilis* does exist in the Narbada valley or its neighbourhood. The occurrence of *M. lyrata*, included in Mr. Theobald's list, l. c., is also very doubtful.

Their absence is not surprising, because land shells, for the most part, float when washed away, and are left on the surface, where they decompose instead of being preserved in alluvial deposits.[1]

Fluviatile origin of Narbada alluvium.—The examination of the molluscan remains in the Narbada clays and gravels completely disproves the idea of a marine origin, but it has been considered by some observers that the deposits are lacustrine.[2] This view was principally based upon the uniform appearance of the clay and the absence of stratification. But this very uniformity and want of stratification are common characters of undoubted river deposits, and may be observed on the banks of most large streams, whilst the frequent deposition of pebble beds throughout the clays could not have taken place in the waters of a large lake. The bones, too, are isolated and broken, sometimes being even rolled, whereas, if deposited in a lake, different bones would in all probability be found together, because away from the margin there could be no current in the lake of sufficient force to transport bones divested of flesh, and any mammalian remains deposited in the bottom of the lake must be derived from floating carcases or portions of carcases. Moreover, the *Chelonia* and fresh-water mollusca are all forms which inhabit either rivers or shallow marshes in river valleys, and it is improbable, if so great a change took place in the area, as would be involved in the replacement of immense lakes, or chains of lakes, by a river valley, that a greater difference would not be produced between the tortoises and fresh-water shells formerly inhabiting the waters and those still living. On the other hand, the fact, that the alluvial formation occupies a rock basin, shews that if the deposits were produced by a river, a considerable upheaval of land must have taken place to the westward. The river Narbada, moreover, is now no longer a depositing stream within the alluvial basin; on the contrary, it has cut its way through a considerable thickness of clays, and it must therefore have a greater fall than formerly. This, of course, may be due to the rocky edge of the basin having been cut through by the river, and by the channel of exit being consequently at a lower level.

Tapti and Purna alluvial plains.—The alluvial plains of the Tapti valley require but brief notice.[3] In their principal characters they resemble the Narbada plain, but the depth of the deposits is unknown, no deep borings having been made. As in the Narbada valley, the river now runs at a considerable depth below the alluvial plain,

[1] See Mem. G. S. I., VI, p. (231).

[2] Mem. G. S. I., II, p. 283.

[3] For a few additional details see Mem. G. S. I., VI, pp. (276), (286); and Wynne, Rec. G. S. I., II, p. 1.

and is evidently cutting its channel deeper, and not depositing at present. The whole basin is composed of the Deccan trap, and the Tapti cuts its way out to the westward through the same formation. No remains of mammalia have hitherto been detected in the alluvium, but they will probably be found if sought after; the few mollusca found, as in the Narbada plain, belong to recent fresh-water species inhabiting rivers.

The difference in elevation between the Tapti and Púrna plains is not accurately known, nor are the levels of different parts of the plains well determined, the only data available being those furnished by the railway. The height above the sea at Bhosawal, just south of the alluvial flat, near the eastern extremity of Khándesh, is 677 feet. This cannot be much above the flood-level of the Tapti river, for the rail-level at the bridge over the Tapti, only about 6 miles distant, is 685 feet. At Malkapur, close to the western extremity of the Púrna alluvial plain, the level is 816 feet, at Akola 917, at Murtazapur 986, and at Badnera, south of Amráoti, 1,093. The last locality, however, is some miles distant from the south-eastern edge of the alluvium, and none of the railway stations are out in the alluvial plain as in the Narbada valley.

The only peculiarity of the Púrna alluvial deposits which deserves notice is the occurrence of salt in some of the beds at a little depth below the surface. Throughout an area more than 30 miles in length, extending from the neighbourhood of Dhyanda, north of Akola, to within a few miles of Amráoti, wells for the purpose of obtaining brine are sunk in several places on both sides of the Púrna river. The deepest wells are about 120 feet deep; they traverse clay, sand and gravel, and finally, it is said, a band of gravelly clay, from which brine is obtained. No fossils are found in the clay and sand dug from the wells. The occurrence of salt in the alluvial deposits of India is not uncommon, and it is impossible to say, without further evidence, whether it indicates the presence of marine beds. The absence of marine fossils in all known cases is opposed to any such conclusion, but still it is not impossible that the land may have been 1,000 feet lower than it now is in late tertiary, or early post-tertiary, times, and this difference in elevation would depress the Púrna alluvial area beneath the sea-level.

Older alluvial deposits of Godavari.—It has already been mentioned that the alluvial deposits of the Godávari do not occur in distinct basins like those of the Narbada and Tapti, but the river in general has but a slight fall, and forms a broad alluvial plain where it traverses softer beds, whilst it cuts a steeper slope through harder rocks.

There is an exception to the latter rule in the gorge above Rájámahendri. Extensive alluvial areas occur along the upper part of the Godávari in the Bombay Presidency and the adjoining portion of the Nizam's dominions, and similar tracts are found on the Pen Ganga (Pyne or Pem Ganga), Wardha, and Wain Ganga, tributaries of the Godávari, in Berar, Nágpúr, and Chánda.

The composition of these deposits differs in no important particular from that of the Narbada and Tapti alluvium. The gravels are chiefly composed of rolled agates and fragments of basalt derived from the Deccan traps, which are the prevailing rocks in the upper part of the valley. The greater portion of the alluvium in all cases consists of brown clay with kankar. In the Wardha valley beneath the clays and calcareous conglomerates some fine sandy silt, light brown or grey in colour, occurs west of Chánda, and contains salt, with a considerable proportion of sulphate of magnesia[1] (Epsom salts).

Bones of mammalia have been found—sometimes, it is said, in large numbers—in the Godávari valley, but very few appear to have been preserved, and the only species identified is *Elephas namadicus*.[2] Bones of *Bos* and other animals occur, and it appears probable that the fauna is similar to that of the Narbada valley. From the gravels near Múngi and Paitan (Pytun) on the road from Ahmednagar to Jálna, Mr. Wynne obtained an agate flake[3] (Pl. XXI, fig. 2), apparently of human manufacture, thus affording a second instance of traces of man occurring in the post-tertiary river gravels of the Peninsula.

The most important localities at which bones have been observed are the neighbourhood of Múngi and Paitan already mentioned, and one or more places on the Pen Ganga or its tributaries in the neighbourhood of Hingoli.[4] At one spot near Hingoli bones are said to have been found in immense quantities, but unfortunately they were not preserved.

Krishna Valley.—The valley of the Krishna, in many respects, resembles that of the Godávari; there are similar plains of alluvial clay with beds of sand, gravel and calcareous conglomerate, but none of these plains appears to be of great extent. Beds of gravel at a height of 60 to 80 feet above the present course of the river and its tributaries have been observed in many places.[5]

[1] Rec. G. S. I., IV, p. 80; Mem. G. S. I., XIII, p. 92.

[2] Falconer, Q. J. G. S., 1865, p. 381; Mem. G. S. I., VI, p. (232).

[3] For a description by Dr. T. Oldham and figures, see Rec. G. S. I., I, p. 65.

[4] Captain O. W. Gray, Mad. Jour. Lit. Sci., VII, p. 477 (1838): Carter on the authority of Dr. Bradley, J. B. Br. R. A. S., V, p. 304: Newbold, J. R. A. S., VIII, p. 246. See also Mem. G. S. I., VI, p. (232).

[5] Newbold, J. R. A. S., VIII, p. 247: Foote, M. G. S. I., XII, p. 237, &c.

The only important mammalian remains[1] hitherto found in the alluvial deposits of the Krishna and its tributaries, consist of portions of the cranium and mandible of a *Rhinoceros*, and some bovine teeth and jaws, found on the Ghatprabha near the town of Gokák. The bovine remains have not been determined; the *Rhinoceros* has been described under the name of *R. deccanensis* by its discoverer, Mr. Foote.[2] The species differs widely from all living forms, and does not appear to be very nearly connected with any known fossil Indian species. Some fresh-water shells, of living species, were found with the bones.

It was probably from some part of the upper drainage area of the Krishna, also, that Colonel Sykes obtained the teeth of a trilophodont *Mastodon*, described by Falconer[3] under the name of *M. pandionis*, Lartet.

Large numbers of chipped quartzite implements of human manufacture, and belonging to the same type as that discovered in the Narbada alluvium, have been found in various gravels in the Southern Máhratta country on the Malprabha and other affluents of the Krishna.[4] The relations between the ossiferous gravels and those containing the implements are, however, somewhat obscure.

Nothing of importance is known concerning the older alluvial deposits of the remaining rivers in the Indian Peninsula.

It is in the Máhánadi, Krishna, and Pennár valleys that the principal diamond gravels are found, frequently at heights considerably above the present stream level.[5] The pebbles in the gravels are composed of various kinds of metamorphic and transition rocks.

[1] Mem. G. S. I., XII, p. 232.
[2] Pal. Ind., Ser. X, 1.
[3] Pal. Mem., 1, 124.
[4] Foote, Mem. G. S. I., XII, p. 241.
[5] Newbold, Jour. Roy. As. Soc., VII, p. 226.

CHAPTER XVII.

PENINSULAR AREA.

POST-TERTIARY AND RECENT—(*continued.*)

Indo-Gangetic alluvium: area and elevation — Origin of the Gangetic plain: no evidence of marine conditions in Upper India — Sub-recent marine conditions in the Indus area — Character of Indo-Gangetic alluvium — Calcutta borehole — Umballa borehole — Fossils in Indo-Gangetic alluvium — General surface features of the Indo-Gangetic plain — Bhábar, Terai, Bhángar, and Khádar — Bhúr land — The Brahmaputra valley in Assam — The delta of the Ganges and Brahmaputra — Mr. Fergusson's theories — The Madapúr jungle — The plains of Upper Bengal and the North-West Provinces — Kalar or Reh — Salt wells — The Punjab — Ancient changes in the course of the Punjab rivers — The lost river of the Indian desert — The Lower Indus valley and delta — The Ran of Cutch.

Indo-Gangetic alluvium: area and elevation.—The immense alluvial plain of the Ganges, Indus, and Brahmaputra rivers and their tributaries, the richest and most populous portion of India, covers an area of about 300,000 square miles, and forms approximately one-fourth of the whole surface of British India exclusive of Burma. The greater part of the provinces known as Assam, Bengal (including Behár), the North-West Provinces, Oudh, the Punjab and Sind, are included in the great plain, which, varying in width from 90 to nearly 300 miles, entirely separates the geological region of Peninsular India from the Himalayas to the north, the Sulemán and Khirthar ranges to the west, and the hill regions of Assam, Tipperah, and Chittagong to the eastward. Owing to the varying extent to which the surface is raised on the margins of the area by the detritus brought by rivers from the hills, and the gradation between the finer deposits of the plain and the coarser gravels forming a detrital slope at the base of the Himalayas, it is difficult to estimate exactly the greatest height of the plain above the sea; the highest level recorded by the Great Trigonometrical Survey between the Ganges and Indus, on the road from Saháranpur to Ludhiana, is 924 feet,[1] and

[1] The following elevations of localities in the Indo-Gangetic plain will afford some idea of the general height of the surface above the sea. The figures, except in the case of Rájmahál, are taken from the maps and published sections of the Great Trigonometrical.

this may be fairly taken as the summit level at the lowest part of the watershed between the Indus and the Ganges. There is no ridge of high ground between the Ganges and Indus drainage, and a very trifling change in the surface might at any time turn the affluents of one river into the other. It is reasonable to infer that such changes have taken place in past times, and that the occurrence of closely allied species of *Platanista* (a fresh-water dolphin peculiar to the Indus, Ganges, and Brahmaputra) in the two rivers, and of many other animals common to both streams, may thus be explained.[1]

Survey, with a few additions kindly furnished by the Surveyor General, Colonel Walker. At all the localities quoted, the height is the approximate level of the plain :

1. BRAHMAPUTRA VALLEY.

Sadiya	440	Sibsagar	319	Gauhati	163
Dibrugarh	348	Buramuk near Tezpur	256	Goalpara	150

2. GANGES VALLEY.

Burdwan	102	Allahabad	319	Delhi	715
Rájmahál	68	Cawnpore	417	Meerut	739
Benares	258	Agra	553	Sahárаnpur	907

3. INDUS VALLEY.

Umballa	901	Dera Ismail Khan	595	Shikarpur	198
Ludhiana	806	Mooltan	407	Sehwan	110
Ferozepoor	645	Baháwalpur	375	Kotri	66
Lahore	708	Kashmor	246		

[1] The occurrence of allied forms of porpoise or dolphin in the Ganges and Indus, and the circumstance that the peculiar genus living in these rivers is unknown elsewhere (the cetacean inhabiting the Irawadi being of a very different generic type), have attracted the attention of naturalists already. The ova and young of fish are not difficult of transport, and a very trifling accident might place a pool of water, to which the fish of one river have gained access, in communication with the other stream; crocodiles and river tortoises can live for a long time out of water, and have considerable powers of migration on land; but dolphins are confined to the rivers, and could neither live in a shallow pool, nor traverse dry land; the existence, therefore, of closely allied species, doubtless derived from a common ancestor, in two distinct rivers, is a very striking fact. Mr. Murray (Geographical Distribution of Mammals, p. 213) has proposed an ingenious hypothesis to account for the phenomenon. He considers that the plain of Upper India was once an arm of the sea; that it was cut off by the rise of the coast in Sind and Cutch, and gradually converted into a brackish, and then a fresh-water lake, discharging itself by the Ganges; that meantime the marine dolphins inhabiting the sea had gradually become adapted to the changed conditions, and had in fact become *Platanistæ*. He then supposes that the Ganges was cut off from the lake, which overflowed again, and this time into the Arabian sea, the dolphins of the Ganges and Indus being specialised during the change. It would be unnecessary to refer to this hypothesis, which of course is little more than a suggestion, but for the large amount of support the idea has received from naturalists. It is of course foreign to the purpose of the present work to discuss the genesis of *Platanista*, but, as will be shewn, the geological phenomena of the Indo-Gangetic plain do not bear out Mr. Murray's hypothesis, which, however, it should be stated, was never proposed as a geological theory, but merely as illustrative of the possible mode of origin of allied species.

No evidence of marine conditions in Upper India.—A common idea amongst both geologists and naturalists is, that the great Indian plain was an arm of the sea in late geological times.[1] It is possible that this may have been the case, but there is absolutely no evidence whatever in favour of such a view, and some facts are opposed to it. On the southern flank of the Himalayas, no marine formations have been discovered of later date than eocene, and even eocene marine beds are unknown, except in one place east of the Ganges, between the spot where the Jumna leaves the Himalayas, and the Gáro hills, or throughout 13 degrees of longitude; whilst the later tertiary formations, belonging to the Siwalik series, contain fresh-water *Reptilia* and *Mollusca*, and not a single marine shell has been found in them. In Sind, marine beds of miocene date are found, and it is possible that strata of the same age may extend to the Punjab, but in the Salt Range the fresh-water Siwaliks rest upon the nummulitic limestone. It is true that it is impossible to tell what beds may be concealed beneath the Indo-Gangetic alluvium, and marine strata may exist to an enormous extent without appearing at the surface; it is also unquestionable that the amount of information hitherto derived from borings is very small indeed, but so far as that information extends, and so far as the lower strata of the alluvial plain have been exposed in the beds of rivers, not a single occurrence of a marine shell has ever been observed, nor is there such a change in the deposits as would render it probable that the underlying strata are marine. As will be shewn presently, the lowest deposits known in the plain itself are of post-tertiary age, and they are certainly fresh-water, whilst the tertiary deposits are chiefly known to occur on the northern margin of the plain. The older pliocene deposits of Perim Island in the Gulf of Cambay lie, however, to the south of the alluvial area, and five species of mammals found in them, *viz.*, *Mastodon latidens*, *M. perimensis*, *M. sivalensis*, *Acerotherium perimense*, and probably *Sus hysudricus*, are also met with in the Siwaliks at the base of the Himalayas, so that there was probably land communication between the two areas. The only evidence known in favour of marine conditions having prevailed during the deposition of any portion of the Gangetic alluvium is the occurrence of brine springs at considerable depths in a few localities. These springs, however, are not numerous, and, without additional evidence, it is impos-

[1] Hooker's Himalayan Journals, I, p. 378: Theobald, Rec. G. S. I., III, p. 19. Mr. Theobald's main argument, derived from the clay at Patharghatta, has been shewn by a re-examination of the locality to be untenable, the deposit in question being merely a surface wash, containing fragments of bricks amongst other things; see Ball, Mem. G. S. I., XIII, p. (224). Dr. Falconer, Pal. Mem., I, p. 29, considered that the Indo-Gangetic area was formerly an arm of the sea, but that it had been converted into land before the Siwalik epoch.

sible to look upon them as proofs of marine deposits. At the same time, it is by no means impossible that the sea occupied portions of Sind and Bengal long after the plain of Upper India was dry land. With reference to Bengal, there is very little evidence. Mr. Fergusson, in a masterly essay on recent changes in the delta of the Ganges,[1] has brought forward a quantity of historical data tending to shew that the whole Ganges valley 5,000 years ago was probably not habitable, and that the extension of human settlements to the eastward from the Punjab has been gradual. This, however, may all be conceded, with the reservation that additional evidence as to the previous want of population is desirable; the Ganges valley 5,000 years ago, like that of the Brahmaputra valley at the present day, may have been so swampy as to be ill-suited for cultivation, and yet there is no reason for supposing that the area had recently been covered by the sea, for the state of the surface may have been due to an amount of depression sufficient to render the area marshy, but not enough to cause it to be overflowed by the ocean. That depression has taken place in the delta, is shewn by the records of the Fort William borehole, to be described presently. The only known marine beds[2] in the neighbourhood of the Ganges delta, those at the foot of the Gáro hills, are apparently of tertiary age, and probably pliocene.

Sub-recent marine conditions in the Indus area.—In the Indus valley some proof has lately been obtained, shewing that the sea may have occupied part of the area in post-tertiary times.[3] East of the alluvial plain of the Indus near Umarkot (Omerkote) is a tract of blown sand, the depressions in which are filled by salt lakes. These lakes are supplied by water trickling through the soil from large marshes and pools supplied by the flood waters of the rivers, and it is evident that

[1] Q. J. G. S., 1863, p. 321. There is one ethnological fact which Mr. Fergusson has not noticed. He considers that Lower Bengal was not habitable 1,000 years ago. Now the population of Bengal, as any one who has seen much of Indian races will probably admit, is shewn by colour, physique, and habits of life to contain a large proportion of the non-Aryan races; the people of Upper India, on the other hand, having a much larger Aryan element. But if the non-Aryan race did not inhabit the country before the advent of the Mahomedans, how comes it that this race is now a preponderating constituent of the population? The mixed race may have migrated into the country, but it is at least as probable that the non-Aryan tribes were indigenous, and that the present Bengali race is due to an admixture of Aryan blood. The point is, whether Mr. Fergusson has not overlooked the fact that the Aryan immigrants are certainly not the oldest inhabitants of India, and whether, as no history of the indigenous races exists, he may not have taken the south-eastern migration of the more civilised population amongst uncivilised tribes for the original peopling of the Gangetic plain.

[2] Colebrooke, Geol. Trans., Ser. 2, Vol. I, p. 135.

[3] J. A. S. B., 1876, XLV, Pt. 2, p. 93; Rec. G. S. I., X, pp. 10, 21.

the depressions amongst the sand-hills are at a lower level than the alluvial plain, and that the salt is derived from the soil beneath the sand. To the southward is a great flat salt tract known as the Ran of Cutch, marshy in parts, dry in others, throughout the greater part of the year, but covered by water when the level of the sea is raised by the south-west monsoon blowing into the Gulf of Cutch and the old mouth of the Indus, and all water which runs off the land is thus ponded back. The Lúni river, which flows into the Ran, is, except after rain, extremely salt, and salt is largely manufactured from the salt earth at Pánchbhadra, close to the Lúni, more than 100 miles from the edge of the Ran, and nearly 300 from the sea. Both the present condition of the Ran and tradition point to the area having been covered by the sea in recent times, and having been filled up by deposits from the streams running into it; and the occurrence in some of the salt lakes near Umarkot, 150 miles from the sea, of an estuarine mollusk *Potamides* (*Pirenella*) *layardi*, common in the salt lagoons and back-waters of the Indian coast, seems to indicate that these lakes were formerly in communication with the sea. The enormous quantity of blown sand, also, which covers the Indian desert, can only be satisfactorily explained by supposing that it was derived from a former coast line north of the Ran and east of the Indus valley.[1]

It appears probable that in post-tertiary times an arm of the sea extended up the Indus valley at least as far as the salt lakes now exist, or to the neighbourhood of Rohri, and probably farther, and also up the Lúni valley to the neighbourhood of Jodhpur; the Ran of Cutch being of course an inland sea.[2] The country to the westward has been raised by the deposits of the Indus, and the salt lakes have been isolated by ridges of blown sand.

It is true that along the western margin of the Indus alluvium later tertiary rocks (Manchhar) are found containing remains of mammalia, and precisely resembling the Siwalik formation, and as there is nevertheless a probability that the lower Indus valley was an arm of the sea in post-tertiary times, it may fairly be argued that the existence of the Sub-Himalayan Siwaliks is no proof that the Ganges valley was not an inland sea at the same epoch. But in the Indus region the representatives of the Siwaliks pass downwards into miocene marine beds; in lower

[1] A description of this area will be found at the end of the present chapter, and the Indian desert is described in the chapter following.

[2] Some additional evidence in favour of this view will be mentioned in the next chapter in connexion with the distribution of blown sand in the desert between Sind and Rajpútána.

Sind the Manchhar formation itself becomes interstratified with bands containing marine shells, and not very far to the westward, on the Baluchistan coast, there is a very thick marine pliocene formation, so that there is evidence in abundance of the sea having occupied portions of the area in later tertiary times, whilst there is no proof of any such marine conditions in the Ganges plain.

Character of Indo-Gangetic alluvium.—The various deposits of the Indo-Gangetic plain[1] may be roughly classed under two sub-divisions, older and newer; the former consisting of beds which are, where exposed, undergoing denudation; whilst the latter form the newer accumulations, the flood and delta deposits now in process of formation. It is difficult, if not impossible, to draw any distinct line of separation between these two sub-divisions, unless, as but rarely occurs, they contain fossils characteristic of their age, but, generally speaking, all the higher ground is composed of older deposits, whilst the newer alluvium is chiefly confined to the neighbourhood of the river channels, except in the delta of the Ganges and in the Brahmaputra plain. Still there are large parts, both of the Indus and Ganges plains, which are flooded every season, and on these areas newer deposits are formed by the flood waters. Moreover, as the rivers constantly change their courses, they often sweep away deposits only a few years, or even a few months old.

The prevailing formation throughout the Indo-Gangetic alluvial area is some form of clay, more or less sandy. The older deposits generally contain kankar; the newer deposits do not as a rule, but there are numerous exceptions in both cases. In the Indus valley the alluvial deposits are much more sandy than in the Ganges valley, and the surface of the ground is paler in colour, except where marshy conditions prevail. The deposits of the Brahmaputra valley in Assam are also sandy. In both these valleys nearly the whole area is occupied by the newer alluvial deposits, whilst the greater portion of the Ganges plain, except towards the delta, is composed of an older alluvial formation.

The older alluvium is usually composed of massive clay beds of a rather pale, reddish-brown colour, very often yellowish when recently exposed to the air, with more or less kankar disseminated throughout. In places, and especially in Bengal and Behár, pisolitic concretions of hydrated iron peroxide, from the size of a mustard seed to that of a pea,

[1] The authorities for the following account are manuscript reports by Mr. Theobald on parts of the alluvial area in Bengal, Behár, and the North-Western Provinces, some extracts from which were published, Rec. G. S. I., III, p. 17; sketch of the Geology of the North-Western Provinces, Rec. G. S. I., VI, p. 9, and various papers to which reference is made in notes.

are disseminated through the clay; occasionally these nodules attain larger dimensions, some being found near Dinájpur (Dinagepore) of the size of pigeons' eggs. In places the kankar forms compact beds of earthy limestone. Sand, gravels, and conglomerates occur, but are, as a rule, subordinate, except on the edges of the valley, the quantity of sand in the clay decreasing gradually as the distance from the hills increases. Pebbles are scarce at a greater distance than from 20 to 30 miles from the hills bordering the plain. Beds of sandstone, sufficiently compact for building, have occasionally been found, but they are of rare occurrence. On the whole, there is no great difference between the alluvial formations of the Indo-Gangetic plain and those of the Narbada and Tapti, except that the latter are rather darker in colour, and perhaps less sandy.

The newer alluvial deposits consist of coarse gravels near the hills, and especially at the base of the Himalayas, sandy clay and sand along the course of the rivers, and fine silt consolidating into clay in the delta and in the flatter parts of the river plain. In the Ganges delta, beds of impure peat commonly occur. Fresh-water shells are of more frequent occurrence in the newer forms of alluvium than in the older, the species being of course those now living in the rivers and marshes of the country.

The denudation of rivers has in some parts of the North-West Provinces cut through the older alluvial clays to a depth occasionally, as on the Chambal river, amounting to nearly 200 feet. Of the whole thickness attained by the alluvial deposits of the great Indian rivers, not the faintest idea can be formed. It must be very great, or rock would be exposed within the alluvial area to a greater extent than it is. The only information of importance hitherto procured as to the nature and depth of the alluvial deposits beneath the surface is derived from three borings: one, 481 feet deep, at Fort William, Calcutta, within the delta and close to a tidal river; the second at Umballa, 701 feet deep, at nearly the highest level of the plain away from the slope of detritus along the margin; the third, carried to a depth of 464 feet, at Sabsal-ka-kot on the right (west) bank of the Indus, about 21 miles east by north of Rajánpur and about 400 feet above sea-level. All these boreholes were made for the purpose of obtaining water.

Calcutta borehole.—The Calcutta borehole is on the whole the most important, because it was carried down to a depth of about 460 feet below the mean sea-level. The following account of the deposits passed through in the borehole is taken from the "Abstract report of the Proceedings of the Committee appointed to superintend the bore

operations in Fort William from their commencement, December 1835, to their close in April 1840[1]:—

"After penetrating through the surface soil to a depth of about 10 feet, a stratum of stiff blue clay, fifteen feet in thickness, was met with. Underlying this was a light-coloured sandy clay, which became gradually darker in colour from the admixture of vegetable matter, till it passed into a bed of peat, at a distance of about 30[2] feet from the surface. Beds of clay and variegated sand intermixed with kankar, mica, and small pebbles, alternated to a depth of 120 feet, when the sand became loose and almost semi-fluid in its texture. At 152 feet the quicksand became darker in colour and coarser in grain, intermixed with red water-worn nodules of hydrated oxide of iron, resembling to a certain extent the laterite of South India. At 159 feet a stiff clay with yellow veins occurred, altering at 163 feet remarkably in colour and substance, and becoming dark, friable, and apparently containing much vegetable and ferruginous matter. A fine sand succeeded at 170 feet, and this gradually became coarser and mixed with fragments of quartz and felspar to a depth of 180 feet. At 196 feet clay impregnated with iron was passed through, and at 221 feet sand recurred, containing fragments of limestone with nodules of kankar and pieces of quartz and felspar; the same stratum continued to 340 feet, and at 350 feet a fossil bone, conjectured to be the humerus of a dog, was extracted.[3] At 360 feet a piece of supposed tortoise shell[4] was found, and subsequently several pieces of the same substance were obtained. At 372 feet another fossil bone was discovered, but it could not be identified, from its being torn and broken by the borer. At 392 feet a few pieces of fine coal, such as are found in the beds of mountain streams, with some fragments of decayed wood, were picked out of the sand, and at 400 feet a piece of limestone was brought up. From 400 to 481 feet fine sand, like that of

[1] J. A. S. B., 1840, IX, p. 686. See also an excellent account by Lieutenant (afterwards Colonel) R. Baird Smith, Calcutta Jour. Nat. Hist., I, p. 324, pl. ix, and Proc. Geol. Soc., IV, p. 4. From the latter the account in Lyell's Principles of Geology appears to be chiefly taken. Some additional details will be found in the Jour. As. Soc. Bengal, II, pp. 369, 649; IV, p. 235; V, p. 374; VI, pp. 234, 321, 498, 897; VII, pp. 168, 466.

[2] Eighty feet in the original, but this is almost certainly a misprint;—first, because Lieutenant Baird Smith mentions in his description the occurrence of peat between 30 and 50 feet from the surface, whereas from 75 to 120 feet sandy clay is said to occur, and this agrees with his descriptive catalogue of the specimens extracted from the borehole, and with his figured section;—secondly, because, as will be shewn hereafter, a bed of peat is found everywhere around Calcutta at a depth of 20 to 30 feet.

[3] A ruminant bone according to Dr. Falconer; Lyell's Principles, ed. 1867, I, p. 479. The specimen cannot now be found. Figures of this bone are given, J. A. S. B., VI, p. 234, pl. xviii; and Calc. Jour. Nat. Hist., I, pl. ix.

[4] Figured J. A. S. B., VI, p. 321, pl. xxi; and Calc. Jour. Nat. Hist., I, pl. ix.

the sea-shore, intermixed largely with shingle composed of fragments of primary rocks, quartz, felspar, mica, slate, and limestone, prevailed, and in this stratum the bore has been terminated."[1]

The first and most important observation to be made on the foregoing facts is that not race of marine deposits was detected, but on the contrary there appears every reason for believing that the beds traversed, from top to bottom of the borehole, had been deposited either by fresh water, or in the neighbourhood of an estuary. At a depth of 30 feet below the surface, or about 10 feet below mean tide-level, and again at 382 feet, beds of peat with wood were found, and in both cases there can be but little doubt that the deposits proved the existence of ancient land surfaces. The wood in the upper peat beds was examined by Dr. Wallich and found to be of two kinds, one of which was recognised as belonging to the Súndri tree (*Heritiera littoralis*), which grows in abundance on the muddy flats of the Ganges delta, the other probably as the root of a climbing plant resembling *Briedelia*. Moreover, at considerable depths, bones of terrestrial mammals and fluviatile reptiles were found, but the

[1] The following details are taken from the figured section by Lieutenant Baird Smith, l. c.:—

	Thickness in feet.	Depth in feet.
Surface soil, loose sand, and clay	10	...
Adhesive blue clay	15	25
Ditto with peat	10	35
Adhesive clay	5	40
Dark clay with decayed wood intermixed	10	50
Calcareous clay with kankar	10	60
Green silicious clay; Silicious clay with kankar; Variegated arenaceous clay — Details of thickness not given, the lower portion represented as much thicker than the others.	60	120
Argillaceous marl	5	125
Loose sandstone	5	130
Argillaceous marl	20	150
Arenaceous clay with weathered mica slate and nodules of hydrated oxide of iron	20	170
Calcareous clay	5	175
Coarse friable quartzose conglomerate	10	185
Micaceous clay	20	205
Soft sandstone	5	210
Ferruginous sand intermixed with clay	90	300
Fine loose sand with minute fragments of felspar and granite	25	325
Sandstone slightly aggregated (first fossiliferous stratum 350 feet)	55	380
Shelly calcareous clay	5	385
Carbonaceous bed	10	395
Coarse conglomerate third fossiliferous stratum 430 feet)	86	481

only fragments of shells noticed, at 380 feet, are said to have been of fresh-water species.

The next noteworthy circumstance is the occurrence at a depth of 175 to 185 feet, again at 300 to 325, and again throughout the lower 85 feet of the borehole, of pebbles in considerable quantities. The pebbles in the lower portion are especially mentioned as large, and their size is shewn by the circumstance that they impeded the progress of the bore, and that it was necessary in several cases to break them up before they could be extracted, so that it may be fairly inferred that they were at least two to three inches across (the borehole was six inches in diameter). The greater part of the pebbles were clearly derived from gneissic rocks, but some fragments of coal and lignite which were obtained were perhaps from the Damuda series.

The peat bed, it may here be mentioned, is found in all excavations around Calcutta, at a depth varying from about 20 to about 30 feet, and the same stratum appears to extend over a large area in the neighbouring country.[1] A peaty layer has been noticed at Canningtown on the Mutlah, 35 miles to the south-east, and at Khulna, in Jessore, 80 miles east by north, always at such a depth below the present surface, as to be some feet beneath the present mean tide-level. In many of the cases noticed, roots of the *sundri* tree were found in the peaty stratum. This tree grows a little above ordinary high-water mark in ground liable to flooding; so that in every instance of the roots occurring below the mean tide-level, there is conclusive evidence of depression. This evidence is confirmed by the occurrence of pebbles; for it is extremely improbable that coarse gravel should have been deposited in water 80 fathoms deep, and large fragments could not have been brought to their present position, unless the streams, which now traverse the country, had a greater fall formerly, or unless, which is perhaps more probable, rocky hills existed, which have now been partly removed by denudation and covered up by alluvial deposits. The coarse gravels and sands which form so considerable a proportion of the beds traversed can scarcely be deltaic accumulations, and it is therefore probable that when they were formed, the present site of Calcutta was near the margin of the alluvial plain, and it is quite possible that a portion of the Bay of Bengal was dry land.[2]

[1] Baird Smith, l. c.; H. F. Blanford, J. A. S. B., 1864, XXXIII, p. 154. See also notices of earlier borings, &c., J. A. S. B., II, pp. 369, 649.

[2] But whilst the evidence of depression to a depth of nearly 500 feet, probably since tertiary times, in the neighbourhood of Calcutta, is unmistakable, the signs already mentioned of elevation within the same epoch in Orissa, only 100 to 200 miles distant to the south-west, are equally distinct, and this proof of unequal movement suffices to shew the hazard of supposing that the general form and direction of the river valleys in the neighbourhood have remained unchanged since the lowest mesozoic, or even the upper palæozoic period; see *ante*, p. 105.

Umballa borehole.—The following is an abstract of the beds traversed in the Umballa borehole.[1] Umballa, it may be mentioned, is on the watershed of the Indo-Gangetic plain, between the Jumna, which flows into the Ganges, and the Sutlej, a tributary of the Indus. The locality is about 905 feet above the sea, and 20 miles from the base of the Himalayas.

	Thickness in feet.	Depth in feet.
Surface soil	4	4
Sand, more or less argillaceous, and clay	22·5	26½
Brown clay and kankar	·5	27
Sand	14	41
Clay, blue and brown	81	122
Sand and clay with kankar	32	154
Dark red clay	12	166
Sand and clay, with bands of kankar	84	250
Stiff red clay and pebbles	14	264
Sand and clay, with kankar occasionally	22	286
Coarse sand, with clay boulders and small stones	10	296
Very stiff clay, with pebbles and boulders	1·5	297½
Clay, with kankar and some sand	12·5	310
Sandy clay, with mica	8	318
Alterations of sand and clay, with kankar occasionally	78	396
Sand and gravel, with large stones	28	424
Clay, with thin bands of fine sand or silt	27	451
Dark sand, with clay boulders and kankar	5	456
Sand and clay	44	500
Clay, with stones	2	502
Sand and clay, with kankar	32	534
Clay boulders, kankar and sand	12	546
Clay, some kankar in the upper portion	39	585
Blue sand, with boulders in the lower portion	16	601
Clay	14	615
Clay, with kankar and pebbles	2·5	617½
Clay, with some kankar	23·5	641
Black clay	3	644
Clay, with kankar in uppermost part	34	678
Sand, which hardens when exposed to air	5	683
Clay, with kankar	18	701

It is not quite clear what is meant by "clay boulders"; they are probably rolled fragments of the clays either from the Siwalik beds, or from the alluvium itself.

There is very little of interest in this borehole. The depth to which it was carried was insufficient to test the thickness of the alluvial deposits, and it ceased 200 feet above the level of the sea. No mention

[1] T. Logia, Q. J. G. S., 1872, p. 198.

is made of any organic remains being found, but their occurrence could not be anticipated, as they occur but rarely in the alluvial formations of the Gangetic plain.

The borehole at Sabzal-ka-kot is only 4 miles from the base of the hills, and by far the greater portion of the beds traversed consist of sand and pebbles, clays being subordinate, although several beds have occurred.

Fossils in Indo-Gangetic alluvium.—The rarity of organic remains, especially in the older alluvial deposits, has already been noticed, but shells are occasionally found belonging to species now inhabiting the rivers and marshes of the country. An important discovery of mammalian remains was made about 1830 in some calcareous shoals of the Jumna.[1] The bones were chiefly found cemented together with substances of recent origin, such as fragments of weapons and boats, into a mass of concrete, chiefly formed of the kankar washed from the river's bank, but in two cases the skeleton of an elephant was found preserved in the clay. In one instance, in which the bones were clearly *in situ*, they were found 4½ feet above the highest flood mark, and 80 feet below the summit of the clay cliff formed by the river, and there appears no reason to doubt that all the specimens found were originally derived from the clay. The following species have been recognised[2]:—

Semnopithecus, sp.
Elephas namadicus.
Mus, sp.
Hippopotamus (*Tetraprotodon*) *palæindicus*.
Equus, sp.
Sus, sp.
Bos (*Bubalus*) *palæindicus*.
Bos, sp.
Antilope, sp.
Cervus, sp.
Fish and crocodile bones.

Three of the species (all that have hitherto been specifically identified) are found in the Narbada alluvium also, whilst the only genus not now found wild in India is the *Hippopotamus*, which belongs, however, to the same sub-genus as the living African animal. The evidence is not sufficient to justify any decided conclusions, except that the Jumna clays must have been deposited in the same post-tertiary epoch as the Narbada alluvium; but so far as the specific identifications go, they tend to indicate that the Jumna fossils are newer than the Narbada remains, as the extinct type, *Hexaprotodon*, and the foreign form, *Bos namadicus*, have not been recognised amongst the former.

[1] Sergeant E. Dean, J. A. S. B., IV, pp. 261, 495. See also Falconer, Q. J. G. S., 1865, p. 378; Pal. Mem., II, p. 640.

[2] Several are figured, J. A. S. B., II, Pl. xxv; and IV, Pl. xxxiii.

Some bones were also found in the Betwa river in Bundelkhand and on the Bugaoti between Mirzapur and Chunár,[1] but they have not been identified.

General surface features of the Indo-Gangetic plain.—To enter at length into the various peculiarities of land surface[2] which are found in different parts of the great plain of Northern India would be far beyond the scope of the present work. A brief account of the principal characters must suffice. The whole region may be roughly divided into five great tracts, each possessing marked peculiarities: these are, commencing to the eastward,—

1. The Brahmaputra valley in Assam.
2. The Delta of the Ganges and Brahmaputra.
3. The plains of Upper Bengal and the North-West Provinces.
4. The Panjáb.
5. The Lower Indus Valley and Delta.

Bhabar, Tarai, Bhangar, and Khadar.—These are four Hindi terms, applied in the Ganges valley to particular kinds of alluvial surface, which require notice, because they will be found freely used in many papers relating to the subject, and because, with perhaps one exception,[3] they have no precise equivalents in English.

Bhábar is the slope of gravel along the foot of the Himalayas. Compared with the slopes in the dry regions of Central Asia, Tibet, Turkestan, Persia, &c., the gravel deposits at the foot of the great Indian ranges are insignificant, the difference in height between the top and bottom of the slope nowhere exceeding 1,000 feet: Mohan at the base of the Himalayas, 24 miles from Sahāranpur, is 1,498 feet above the sea, or 591 above Sáharanpur. This difference is probably partly due to the much greater rainfall in India, and to streams being consequently able to carry away a much larger proportion of the detritus washed from the surface of the hills, partly also to the circumstance that the rocks in the lower regions of the hills are not subjected to the loosening effects of frost.

[1] J. A. S. B., IV, p. 571.

[2] The following papers may be consulted for fuller accounts:

For Assam—Mem. G. S. I., IV, p. 437; VII, p. (155).

For Lower Bengal and the delta—Mr. Fergusson's paper, Q. J. G. S., XIX, 1863, p. 321; also Colebrooke, As. Res., VII, p. 1; and Rennell, Phil. Trans., 1781, p. 78.

For the plains of Upper India—Rec. G. S. I., VI, p. 9; Sir P. Cautley, Ganges Canal; Falconer, Q. J. G. S., 1865, p. 377; Login, Q. J. G. S., 1872, p. 186.

For the Panjáb—the sketch of the Geology published in the *Gazetteer*.

[3] The exception is *khádar*, which corresponds to the English word *strath*. The English term is, however, local; its exact meaning is far from commonly known, and it is only used in hilly country.

Streams, issuing from the Himalayan ranges, lose a part, or the whole of their water, by percolation through the gravel in the *bhábar* region. The whole tract in its original condition is covered with high forest, in which the sál (*Shorea robusta*) prevails. At the base of the slope, much of the water which has percolated the gravel re-issues in the form of springs, the ground is marshy, and high grass replaces the forest. This tract is the *tarai*, a term not unfrequently applied to the whole forest-clad slope at the base of the Himalayas, known also as *morung* in Nepal.

The alluvial plain itself, in the North-West Provinces especially, is composed of *bhángar*, or high land, the flat of older alluvium now at a considerable elevation above the rivers which traverse it; and *khádar*, or low land, the low plain through which each river flows. The latter has evidently been cut out from the former by the streams; it is of variable width, and is annually flooded.

Bhur land.—In the Upper Provinces the high banks of the rivers are frequently capped by the hills of blown sand, known in the North-West Provinces as "bhúr." This is the extreme form of a rather important element in the formation of Indian river channels, and the same result in a less marked form may be traced in a rather sandy, raised bank, along the course of many large rivers down to the limits of tidal action in the deltas. In the lower parts of the river plains this bank, which is above the flood-level, and is usually selected for village-sites, intervenes between the river channel proper and the marshy ground liable to annual floods on each side, the communication between the two latter being kept up by numerous creeks. The origin of the *bhúr* land, or raised bank, is the following. During many months of the year, and especially in the hot season, strong winds arise, frequently of a very local character, and sometimes apparently almost confined to the river channels, which, in the dry season, are plains of loose sand often 2 or 3 miles across and sometimes wider, the river occupying usually not more than a fourth of its bed. The wind on the Indus and Ganges frequently blows in nearly the same direction as the river channel. Such winds are especially prevalent about midday and in the afternoon, and their effect in transporting the sands of the river bed is so great, that the atmosphere becomes too thick for objects a few yards distant to be seen. All who have been in the habit of navigating Indian rivers must have noticed the prevalence of these sand storms; they are so marked that where large sand-banks exist to windward of the river, it is often impracticable for vessels to continue their course, except in the morning before the wind arises, or in the

evening, when the motion of the air has diminished. Much of the sand raised by the wind falls again in the bed of the river, but quantities must fall upon the banks in the immediate neighbourhood, where the deposit is retained by vegetation and gradually consolidated into a firm bank. It is only where the quantity of sand is greater that blown sand hills are formed. The original raising of the river bank to the flood-level is due to the deposition of silt in a manner which will be explained presently when treating of deltaic accumulations, but the elevation of the immediate neighbourhood of the river bed above the reach of the highest floods is probably due to the deposit of sand by the wind.

The Brahmaputra valley in Assam.—The Assam valley is a gigantic *khâdar* or strath, the greater portion being liable to flooding and consequently not in a habitable state. There are, however, here and there higher tracts, sometimes mere mounds rising a little above the general level, and sometimes small plains,[1] and these may be considered as representing the extensive *bhângar* of the Gangetic plain. Along the foot of the hills are gravel deposits, but they do not appear to be very extensive.

The quantity of silt carried down by the Brahmaputra is very great, far greater than in the Ganges. The comparative backwardness of the river valley, as shewn by the small amount of habitable land, is surprising, since it is evident that the river is occupied in rapidly raising its plain by deposits of silt, and the necessary inference is, that the alluvial plain of Assam, in its present form, is not only of later date than the Gangetic plain, but absolutely newer than many portions of the Ganges delta.[2] The difference may be due (1) to a depression of the lower part of the Brahmaputra valley in Assam; (2) to an elevation of the delta; or (3) to a great increase in the supply of water. The second theory is distinctly disproved by the general evidence of subsidence in the delta, and the third is improbable; the evidence is therefore rather in favour of the Brahmaputra valley in Assam having been an area of subsidence in a relatively late geological period. As will be shewn presently, there is some additional evidence in favour of this view within the delta itself.

The delta of the Ganges and Brahmaputra.—The limits of the actual delta, of course, correspond with the spots at which the rivers

[1] Mem. G. S. I., IV, p. 438. One of these plains is described by Major Godwin-Austen, J. A. S. B., 1875, XLIV, Pt. 2, p. 40.

[2] For a full discussion of this argument, see Fergusson, Q. J. G. S., 1863, pp., 330, &c. It should, however, be noticed that Mr. Fergusson was led by some published barometrical observations, now shewn to have been insufficient, to suppose the level of the Brahmaputra valley at Gauhati to be only about 100 feet above the sea, instead of 163, the maximum flood-level since determined by the Great Trigonometrical Survey.

commence to bifurcate and become distributaries. This spot is at present in the Ganges between Rájmahál and Murshidabad, and on the Brahmaputra opposite the south-east corner of the Gáro hills.

But for a considerable distance above the actual delta the rivers flow through a broad plain of low ground, a large area of which is liable to flooding, and consequently to the deposition of silt. The delta is, in fact, the natural continuation of the *khádar* or alluvial flat in the upper portion of the river's course, and this *khádar* becomes broader before it expands into the delta.

Mr. Fergusson's theory.—By far the best description of the Ganges delta, of the changes it is undergoing, and of the action of the rivers in raising the land by the deposition of silt, is that of Mr. Fergusson.[1] He has shewn that rivers oscillate in curves, the extent of which is directly proportional to the quantity of water flowing down the channel. Thus the oscillations of the Ganges where broadest (7,000 feet in the low season), between Monghyr and Rájmahál, average 9½ miles in length; where it contains less water, and is only half the breadth (3,500 feet), between Allahabad and Chunar, the oscillations are 3·7 miles long; in the Bhagirati (Bhagiruthee), where it averages 1,200 feet in breadth, the length of the oscillations is 1·5 miles; and in the Matabangah, where only 500 feet broad, the length of each oscillation becomes only half a mile.[2] The next point which he notices is well known, the tendency of rivers to raise their banks, but the explanation is partly novel. When the whole country is covered with water, moving rapidly towards the sea in the river channels, and stationary throughout the intervening marshes, the dead water of the marshes prevents the floods of the rivers from breaking out of the channels, and, by stopping the course of the silt-charged water along the edges of the creeks and streams, forces it to deposit the sediment it has in suspension. Hence gradually arises a system of river channels, traversing the country in many directions, between banks which are higher than the intervening flats, and these flats form persistent marshes, known in the Ganges delta as *jhils* or *bhils*.[3]

Each river frequently changes its precise course, the smallest alteration in its channel having an effect which is felt for many miles above and below, so that, just as the oscillations of a denuding stream produce a low alluvial flat between high banks, the curves of a depositing river gradually form a high alluvial flat, raised above the surrounding country.

[1] l. c.
[2] l. c., p. 324.
[3] The former term is Hindi; the latter, Bengali. A further stage in the process by which the bank of a river is raised above the surrounding country through the action of wind has already been explained, see p. 404.

In course of time, this raised tract is abandoned by the main river for the lower ground at the side, and the river bed is either filled up by silt, or, if near the sea, converted into a tidal creek.

According to Mr. Fergusson's data, rivers at a greater slope than about 6 inches in a mile cut away their banks; those with a lower slope deposit silt. The precise limit is not ascertained, and it should be recollected that under favourable conditions, as when issuing from hills, coarse materials are deposited at any part of a river's course, provided the slope of the channel diminishes. The approximate limit of silt deposit only applies to rivers running in an alluvial plain.

The present Bengal delta, therefore, comprises a large area in which the ground has been raised above the general flood-level, through having been traversed by the main branches of the Ganges in past times. Such is the case in the country north of Calcutta. The eastern part of the delta is more backward; the marshes or *jhils* are more extensive, and the banks of the streams less consolidated, and this is now the great depositing area. But large tracts of low country, such as the salt lake near Calcutta, are found in the western area also. The remarkable struggle which takes place between the Ganges and Brahmaputra, each tending, by raising the neighbourhood of its channel, to drive back the other, and to gain possession of a larger tract of delta, is most vividly told by Mr. Fergusson, but is too long for extract here. Mr. Fergusson refers many of the more modern changes in the delta to the upheaval of the Madupur jungle, a great tract running for 70 miles north from Dacca and consisting of *bhángar*, or old alluvium, above the general level. The upheaval of this tract, which is about 35 miles wide where broadest; and, on its well-defined western face, whence it slopes gradually to the eastward, 100 feet above the alluvial plain, had the effect, in Mr. Fergusson's opinion, of diverting the Brahmaputra to the eastward into the Sylhet *jhils*, where the silt of the river was deposited. The result was that scarcely any sediment found its way to the sea by the Megna, the great estuary of all the Sylhet rivers, and hence the sea-face of the delta to the eastward curves back in the form of a gulf. The gap was much greater at the commencement of the present century, but about that time the Brahmaputra having, by the deposit of silt, greatly raised the portion of the Sylhet *jhils*, into which it flowed, changed its course completely in the course of a few years, and, instead of flowing to the east of the Madupur jungle, cut out a new channel to the west of the raised tract. Since its change, of course, the Brahmaputra has been brought much nearer to the main stream of the Ganges, and the two rivers are now depositing silt so rapidly on the eastern sea-face

of the delta, that great changes are taking place, and new islands are rapidly forming, whilst the western portion of the deltaic coast line, through which but a small portion of the flood water of the great rivers finds its way to the sea, has undergone but little change since it was first surveyed in the last century.

In the sea outside the middle of the delta there is a singularly deep area, known and marked on charts as the "Swatch of no ground," in which the soundings, which are from 5 to 10 fathoms all around, change almost suddenly to 200 and even 300 fathoms. This remarkable depression runs north and south, and has been referred to a local sinking, but it appears more probable, as has been shewn by Mr. Fergusson, that the sediment is carried away from the spot, and deposition prevented, by the strong currents engendered by a meeting of the tides from the east and west coast of the Bay of Bengal. Mr. Fergusson also shews that, so long as the Bay of Bengal has preserved its present form,[1] the meeting of the tides must have favoured the formation of a spit of sand along the present position of the Sundarbans, as the lower portion of the Ganges delta is called, and that any great deposit of silt to seaward of the present line is impeded by the fine sediment being washed away by the tidal currents, and deposited in the deeper parts of the Bay.

The Madupur Jungle.—The chief point in the above series of theories to which exception may be taken is the question as to whether the Madupur jungle is really an area of elevation. This may be the case, but it is manifest that precisely the same deflection in the course of the river as is attributed to the elevation of the ground north of Dacca, may have been produced by the depression of the area now occupied by the Sylhet *jhils*, and such a depression appears more in accordance with our present knowledge of the delta. Enquiries into the ultimate cause of all the changes by which rivers are converted from denuding into depositing agents, or by which they are made to cut a channel at a lower level through the beds which they formerly deposited, are surrounded by so many difficulties, owing to the magnitude of the operations, and the small differences of level to which such great results are due, that it is not advisable hastily to conclude that either of the explanations above suggested is correct. That some change of level must have taken place since the alluvium now forming the Madupur area was deposited, seems clear, because the ground of the area is higher than the present valley

[1] This is probably not so old as pliocene, because such gigantic disturbance has taken place throughout the extra peninsular regions of India, inclusive of the Assam hills and Arakan, since the close of the Siwalik epoch, that the shape of the northern part of the Bay of Bengal may have changed greatly.

of the Brahmaputra to the north and west, or than the old valley leading to the Sylhet *jhils* to the eastward. There are three possible explanations: the Madupur jungle may have been raised; parts of the surrounding country may have been depressed; or thirdly, the alluvium of the Madupur area may have been deposited by some other river than the Brahmaputra. The last hypothesis appears unsatisfactory, for the Gangetic streams could not have crossed the low area to the westward, and it is improbable that the Sylhet streams, the Surma, &c., which are said to contain comparatively little silt, could have raised their plain to so considerable a height; moreover, they could only have reached the tract north of Dacca if the area now occupied by the Sylhet *jhils* was so much higher than it now is, as to be able to deflect their course to the northward. The only satisfactory explanation involves a partial and unequal change of level, either of depression or elevation.[1] It has already been noticed in the description of the Assam valley, that the singularly marshy condition of the surface of the river may be due to a late action of depression. Earthquakes are of common occurrence both in Assam and Sylhet, and they are frequently severe; and although it would be absurd to conclude, without further evidence, that they are caused by depressions of the surface, it is certain that they have accompanied such movements elsewhere. It does not appear, on the whole, impossible that both the Brahmaputra valley in Assam and the area of the Sylhet *jhils* have sunk in comparatively recent times; that the Madupur jungle has escaped the action of depression, and that this raised tract marks the original level of the Brahmaputra deposits. But it is equally possible, even admitting the depression of the Assam and Sylhet areas, that the tract north of Dacca has been slightly raised.[2] So far as the Madupur jungle alone is concerned, the presence of this and similar masses of *bhángar* land might be due to depression in the delta, and consequent denudation of the ground traversed by the rivers on their way to the deltaic area of depression, but, admitting that the highest level in the Madupur jungle is the ancient flood-level of the Brahmaputra plain, we have to account for the very small difference between the level in question and that of the Brahmaputra valley 200 miles farther up at Gauhati. We can scarcely suppose that all the old *bhángar* has

[1] It may be useful to call attention to the remarkable results of the earthquake of 1819, and its effects on the western portion of the Ran of Cutch, as an illustration of the manner in which a portion of an alluvial area may be elevated, whilst another tract is depressed, during a single series of earthquake shocks. There is some question, however, whether elevation really took place. It is usual to ascribe elevation and depression to the earthquake; perhaps it would be more correct to attribute the earthquake to the elevation or depression.

[2] Mem. G. S. I., IV, p. (440); VII, p. (156).

been swept out of Assam, but if not, some rises of old alluvium should be left as high above the general level as the Madupur jungle is. As no such raised tracts exist, we are driven back again to a local depression of the Assam valley, or of parts of it.

On the western edge of the delta in Bengal there is a large area of older alluvium, the surface of which is slightly undulating, evidently in consequence of partial denudation of the surface. This tract, which is continuous with the alluvial area of the east coast, comprises the greater portion of the country to the westward of the Bhagirati and Hooghly, and probably owes its comparative elevation to the deposits from the More, Adjai, and Damúda rivers.

Plains of Upper Bengal and North-West Provinces.—The great plain of Northern India is the area of an alluvial deposit older than that of the delta, and the greater portion of the area is composed of *bhángar* land, through which the rivers cut their *khádar* valleys at a depth of from 50 to 200 feet below the general level. The *bhángar* surface, as a rule, is nearly flat, but is much cut up by ravines in the neighbourhood of the rivers.

The question as to whether the great rivers are, as a rule, raising their beds by a deposit of silt, or cutting their channels deeper, has been much discussed without leading to any definite conclusions. The abrupt scarps by which the *bhángar* is not unfrequently terminated, and the defined limits of the *khádar*, clearly prove that the latter has been at some time or other an area of denudation, but it is not easy to tell whether, at the present time, in any given stream, the tendency is to raise or lower the general *khádar* level. It is also by no means so evident, as might at first sight be supposed, whether the *bhángar* land generally is an area of denudation or of deposition, although this can, as a rule, be easily seen in each particular area: thus, between the Sutlej and Jumna, the minor hill streams from the lower ranges of the Himalayas must deposit sediment, for they cease within the area, whilst between the Jumna and the Ganges numerous streams rise in the *bhángar*, and they must be denuding agents. In the neighbourhood of the *khádar*, *bhángar* land is frequently cut into by ravines, which prove conclusively that the surface of the country is being washed away, but all such marks of rain-action cease at no great distance from the low ground, and the principal secondary streams, instead of running from the upland *bhángar* by the nearest route, at right angles, or nearly at right angles to the main river, usually pursue a nearly parallel course down the middle of each "doab"[1] or triangular area between each two principal streams.

[1] A Persian word, meaning two waters, and applied to the confluence of two rivers, as well as to the land intervening between them.

The longitudinal section of every river channel in the Gangetic plains, for some distance at all events after leaving the hills, would be found, if drawn accurately, to be slightly concave, the fall at the exit from the hills being greatest, and gradually diminishing. The result of this is, that so long as diminution takes place in the fall, and consequently in the velocity of the water, there must, when the river is carrying as much earthy matter as it can transport, be a continuous deposition of detritus; the coarsest particles, such as large pebbles and gravel, being first left behind, then fine gravel, then sand; but so long as the fall diminishes, there must be deposition and a gradual raising of the area flooded by the stream. In the larger rivers this is the case, if at all, to a minor extent, because there is, at all times, a considerable body of water in the river, and this is sufficient to remove from the channel during the drier months of the year, when little or no coarse detritus is brought down from the hills, the deposits of the rainy season, when the water is charged with the products of pluvial denudation. But the effect of the small streams, which dry up more or less for a great portion of the year, but which are converted into muddy torrents charged with coarse sediment during the heavy rains of the summer monsoon, is to raise the surface of each "doab," especially in the neighbourhood of the hills, and to produce floods from which finer sediment is deposited on the surface of the *bhángar* land. Whether the addition thus produced is, on the whole, greater than the wasting of the surface from rain, is a question which it is impossible to decide throughout a great part of the country.

The careful levels which have been taken throughout the North-West Provinces by the Great Trigonometrical Survey, and the far more accurate maps which are now in process of compilation, will probably, in the course of a few years, furnish definite data for a solution of this and other problems. One question, however, which presents itself, is the necessity of accounting for the rivers now cutting their channels at a level considerably below that of the alluvial *bhángar* flat, because this flat must, at all events in the neighbourhood of the *khádar*, have been deposited by streams from the same drainage area, at a period when the main river ran at a comparatively higher level. The change may be due to a general elevation of the upper Gangetic plain, or to a depression in the delta region. Of the former there is no evidence; of the latter, as shewn by the result of the Calcutta borehole, there is ample proof, and it is therefore quite possible that in early post-tertiary times, when the animals lived, of which remains are found in the Jumna alluvium, the area of the Ganges delta had been raised to a considerably higher level than it

occupies at the present time. Colonel Greenwood[1] has shewn that the deposit of silt in river valleys must take place backward; that the lowest portion of the slope must be first raised, and that the check thus given to the flow of water will cause silt to be deposited so as to raise the alluvial plain further up the course of the river, and if no change of level takes place, the gradual elevations of the Ganges delta by silt deposit will ultimately react on the higher portions of the valley until the rivers once more deposit alluvium on the high *bhángar* land, provided always that this has not been raised so much as to render the slope too great for the rivers to be depositing agents.

One point of interest has been explained by Mr. Fergusson in the paper so often mentioned. A glance at the map will shew that the Ganges from Allahabad to Rájmahál, and the Jumna from Delhi to Allahabad, flow close to the southern margin of the great alluvial plain. This is due to the enormous quantity of silt brought down by the Himalayan rivers, and the comparatively small supply furnished by those streams which debouch into the Ganges valley from the southward. The northern portion of the plain has consequently, been raised, and the main outlet of the whole forced to find its way as close to the hills of the southern margin as it can. During this process, the courses of the tributary rivers running from the northward have been driven westward, and, as Mr. Fergusson has shewn, the confluence of these tributaries with the main stream of the Ganges has been shifted upwards along the course of the main river, owing to the tendency of the streams to deposit silt in the neighbourhood of the delta.

The *bhábar* slope of gravel along the foot of the Himalayas, although evidently of comparatively recent formation, has frequently, to the eastward, been cut into terraces by the streams from the hills.[2] This is a necessary consequence of the streams cutting deeper channels in the rocks of the hilly ground. It is curious to note, however, that to the westward the *bhábar* is being raised instead of being cut through by streams. The difference is not improbably due to the much greater rainfall to the eastward, and to the streams being consequently able to carry away the

[1] Rain and Rivers, pp. 173, &c.

[2] Hooker, Himalayan Journals, I, p. 378, (larger edition). Dr. Hooker very naturally, writing nearly 30 years ago, when the study of river action was in its infancy, and when nearly all great deposits and all extensive denudations were supposed to be marine, attributed the gravel to a beach deposit, and the valleys to marine denudation. There has been since 1850, when Hooker wrote, a great revolution in those portions of geological dynamics which treat of the action, both destructive and constructive, of rivers and the sea, and especially in the views held, by English geologists at least, on the comparative amount of work done by the two agents.

gravel as they cut back their bed in the rock, whereas weaker streams are prevented from cutting back their channels by their inability to wash away the gravel they have already deposited. It may be, too, that from local causes the gravels to the westward are more easily percolated by water, and therefore streams, instead of carrying away the *bhabár* deposits, sink into them; but, judging from the enormous development of the gravel slopes in regions of small rainfall, it is more probable that the first hypothesis is correct.

Kalar or Reh.—In connection with the surface of the Upper Provinces another peculiar local feature requires explanation. Many tracts of land in the Indo-Gangetic alluvial plain are rendered worthless for cultivation by an efflorescence of salt, known in the North-West Provinces as *Reh,* and further west as *Kalar* (Kullar). The name *úsar,* meaning barren, is frequently applied to land thus affected. The salt varies in composition; it consists chiefly of sulphate of soda mixed with more or less common salt and carbonate of soda; it is only found in the drier parts of the country, being unknown in damper regions, such as Bengal.

The *úsar* plains have existed for an unknown time. Where the *reh* or *kalar* is abundant, the water in the upper stratum is impregnated to an extent that is productive of serious injury to the health of the population. To a greater or less extent, this pollution of the water near the surface is general throughout Upper India; yet in the worst *reh* tracts, sweet water is obtainable at depths below 60 to 80 feet.

It is consequently clear that the impregnation of the soil is superficial, and as the upper deposits are demonstrably of fresh-water formation, they must originally have been comparatively free from impurities. Still all soils contain some salt, and all the water draining from soils is impregnated to a certain extent. The salts forming *reh* or *kalar* appear to be the refuse products, and to consist of such substances resulting from the various processes involved in the decomposition of rock, or of detritus derived from rock, and the formation of soil, as are not assimilated by plants. Unless these salts are removed, they must accumulate, and the natural process of purification is evidently by percolation-drainage, so long as pure rain water, running through the soil, carries off any injurious excess of the rejected salts. If the amount of water percolating the soil be sufficient, and thorough drainage exists, there will be a constant dilution and renewal of the subsoil water; but if the quantity of water reaching the subsoil is no more than can be dissipated by evaporation, during the dry season, salts will accumulate in such subsoil water, and as this water is brought to the surface by

capillary action, and evaporated, the salts held in solution will be left as an efflorescence on the surface of the ground.

That the composition of *reh* does not differ greatly from that of the salts produced by the decomposition of such rocks as have contributed by their disintegration to the formation of the alluvial plains of India is shewn by the composition of the river water[1] running from the Himalayas, the mountains from which the detritus now forming the plains of India was originally derived.

In the case of Upper India it is easy to understand how the subversion of the natural conditions necessary for cultivation has been established, and it is by no means improbable that a similar process has, in other parts of the world, changed countries, once fertile and populous, into barren deserts. The whole country is treeless; for a great part of the year a scorching sun and a parching wind dry up the moisture in the ground, rendering it hard and impervious to water; when the rains of the monsoon season fall, a large proportion of the water runs off the surface, and the earth is unable to absorb more than a portion of what remains. Thus a great part is evaporated without penetrating the ground; the little that does percolate through cracks, and in a zig-zag way, through the more porous layers, to the upper water-stratum, is no more than sufficient to replace what has been dissipated by evaporation, fed by capillary action.

This more or less complete want of water circulation in the subsoil must have been gradually producing its effects in Upper India throughout many generations. The natural process is so slow, that it would escape notice, were it not that from time to time larger tracts of land become barren. A disturbing cause has, however, been introduced in the form of great irrigation canals. Their immediate effect is to raise the level of the *reh*-polluted subsoil water, and thus to produce a great increase of evaporation, with the natural result of more *reh* being left on the surface, and more land being thrown out of cultivation. This effect of the canals is evident, and an obvious check upon it would be to keep the irrigation channels at a considerable depth below the surface of the ground. Such a plan, however, involves fresh engineering difficulties, and only meets one of the objections to the present form of irrigation. It is impossible to enter at length into the subject here, but it may be stated that, as all canal water contains salts in solution, whilst rain-

[1] In several analysis of river and canal water from the Ganges and Jumna, the proportion of sulphate of soda varied from 0. 0914 to 0. 4325 part in 10,000; chloride of sodium from 0. 0023 to 0·15 part. The proportion of the two to each other is similar to that found in reh. See Sel. Rec. Govt. India, D. P. W., No. XLII, 1864, pp. 47, &c.

water contains none, the only change in conditions, so far as the concentration of salts in the soil is concerned, by the addition of canal irrigation, unless facilities for drainage of the subsoil water are also provided, must be the addition of all the refuse salts contained in the canal water to those which would be produced on the surface by the simple action of rain and evaporation.

Salt wells.—South and west of Delhi and west of Agra, brine is obtained in places from wells in the alluvium. No particulars have been recorded which explain the occurrence of salt in these localities. The case is similar to that already mentioned in the Púrna valley in Berar. The distribution of the salt-producing ground appears irregular, and this is in favour of the salt being derived from springs in the rock beneath the alluvium.

The Panjab.—The plains intersected by the five great rivers which combine to form the lower Indus are not, as a rule, simply divided into *bhángar* and *khádar*, like the plains of the North-West Provinces. The fall in the Panjáb rivers is much more rapid, and their tendency to desert their channels and to take a new course is much greater; in fact, a great portion of the Panjáb is evidently composed of recent deposits, and is geologically very much in the condition of Upper Assam. The reason why the Panjáb plains are deserts instead of marshes is, that the area over which the water can spread is much greater, whilst the average rainfall is far less. In the Western Panjáb, the barren region, the annual fall of rain only amounts to from 6 to 8 inches, whereas in Assam it is from 66 to over 100.

Owing probably to the greater fall in the Panjáb rivers, their deposits are very sandy, and this character tends to diminish the pluvial denudation of the surface by allowing the water to sink into the soil. The action of winds upon the sand of the river, the formation of bhúr land, and the elevation of the ground in the neighbourhood of the river banks above the intervening tracts, through the deposition of blown sand, are exhibited in the Panjáb to a greater extent than in the Gangetic plain.

To the south-east the limits of the Panjáb alluvium are difficult to trace, owing to the manner in which both alluvium and rock are concealed by blown sand. The same is the case throughout the eastern margin of the Indus alluvial plain in Sind.

Ancient changes in the course of the Panjab rivers.—The ancient geography of the Panjáb is far better known than that of most parts of India, partly because the civilisation of North-Western India is older than that of other parts of the country, but still more because of

the accurate descriptions given by Greek writers of the Indian campaigns of Alexander the Great. It is consequently possible to form some idea of the principal alterations which have taken place in the course of the last 2,000 years, in the channels of the great Panjáb rivers. Unfortunately, our best guide fails us at the most critical point. Alexander never penetrated to the eastward beyond the land of the five rivers, and there is but little except vague tradition to tell whether the present tributaries of the Indus have ever flowed into the Ganges, or, *vice versâ*, those of the Ganges into the Indus. Yet it is certain that in no part of the great Indo-Gangetic plain have more important changes taken place since the dawn of history than in the neighbourhood of the watershed between the Indus and Ganges.

The lost river of the Indian desert.—The traditions of the Hindus point to a time when a great and sacred river, the Sarasváti, ran in the extreme east of the present Panjáb, between the Sutlej and the Jumna. The modern Sarasváti is an unimportant stream, fed by small tributaries from the outer Himalayan ranges, deriving none of its water from snows, becoming nearly dry in the hot season, and losing itself in the Rajpútána desert. According to some traditions,[2] this river formerly followed an independent course through the desert to the sea; and it is a curious fact that, on some maps, a stream, bearing the name of Sarasváti, is shewn running into the smaller division of the Ran at the head of the Gulf of Cutch. It is doubtful, however, whether there is any belt of country between the Arvali range and the Eastern Nara at a sufficiently low level to have permitted a river to run through Western Rajpútána from the Eastern Panjáb to the Ran, and another view, which is certainly supported by much stronger evidence, is, that the Sarasváti formerly joined the Sutlej, and that this pursued an independent course to the sea, under various names, of which the best known are Hakra, Sotra, and Wahind. The course of the lower portion of this old river coincides with the Eastern Nara in Sind,[3] and the upper part ran through a portion of the desert south-east of Baháwalpur,

[1] Cunningham, Ancient Geography of India, p. 220.

[2] Rogers, Q. J. G. S., 1870, p. 124. For further information on this interesting subject, which it is impossible to treat at length here, see Cunningham's Ancient Geography of India, l. c. Fergusson, Q. J. G. S., 1863, p. 348; and a very interesting, but anonymous, paper entitled "Notes on the lost river of the Indian desert," Calcutta Review, 1874, No. CXVII, p. 1.

[3] This must be considered as doubtful. The Eastern Nara runs through a series of broad marshes, and if a great river ever, in recent times, followed the course of the Nara, it is very singular that these marshes were not filled up to a greater extent by alluvial deposits.

where numerous mounds and other relics of old cities remain to attest that the country was once far better watered than it now is. It is an indubitable matter of history that the Beas (Biyas or Vipasa, the Hyphasis of the Greeks) formerly did not join the Sutlej, but pursued a distinct course to the Indus, and the union of the Sutlej with the Beas is very probably due to the former river now running more to the westward than it did.

The diminution in the volume of the Sarasváti has been attributed to various causes, a decrease in the rainfall amongst others, and especially to the destruction of forest on the lower slopes of the Himalayas. The latter has very probably produced a considerable decrease in the quantity of water running down the river during the dry season, but it is not improbable that Mr. Fergusson's suggestion[1] is correct, and that owing to the Sarasváti having raised its channel, whilst the Jumna has cut down its *khádar*, the water which formerly supplied the former river now runs into the latter.

The Lower Indus Valley and Delta.—The surface of the Indus alluvium in Upper Sind differs but little from that of the Panjáb; a considerable portion of the area is annually flooded, and the whole drainage of a great river being here, as in Assam, confined to a comparatively narrow tract, some permanent marshes of large size exist. The two most important marshy tracts are along the western edge of the valley from near Jacobabad to the Manchhar lake (a large *jhíl*) near Sehwán, and along the eastern edge from Khyrpur to below Umarkot. The latter is the channel considered by some the ancient course of the Sutlej. In the neighbourhood of the Indus the ground is rather higher, having evidently been raised by the deposit of silt, aided doubtless by the action of the wind on the sands of the river-bed.

Along the edge of the Khirthar range west of Sind, there is a well-marked *bhábar* slope of gravel, but, except where rivers run out of the range, the breadth of the slope seldom exceeds 1 to 2 miles. This gravel slope is absolutely barren, and, like other features in Sind geology, is more conspicuous on account of its barrenness.

There is one singular feature in the Indus Valley, to which nothing parallel is to be found in the Gangetic area. The river between Sukkur and Rohri has cut its way through a low range of limestone hills, surrounded on all sides by alluvial deposits; even to the south-east, where the limestone disappears beneath sandhills, the Eastern Nara, fed by the flood waters of the Indus, traverses an alluvial tract eastward of the hills. In fact, the circumstance that the flood waters of the Indus, both to the east and west, traverse plains at a lower level than the river-bed,

[1] l. c., p. 348.

is shewn by the course of the canals, and great fears have been entertained that the Indus may desert its present channel, and break out to the westward, through the plain in which Jacobabad is built, into the line of marshes already mentioned. The curious features of the tract are not even confined to the present river-course, for at Arur, 4 miles south-west of Rohri, there is another gap in the limestone range, said, on what is believed to be good historical evidence, to have been the bed of the river rather more than nine centuries ago. At that time the main stream is supposed to have traversed Sind considerably to the east of its present course; it passed by the old city of Brahminabad, 60 miles north-east of Hyderábád,[1] and then probably ran southward by the Purán, an old river-bed still existing, to the Kori creek, which was the principal mouth of the river. The Indus is said to have deserted its old bed at Arur or Alor for its present channel between Sukkur and Rohri, in consequence of an earthquake about A.D. 962; and as Brahminabad was also, in all probability, destroyed by an earthquake[2] at some period prior to A.D. 1020, it is not impossible that the two events were due to the same cause. The Indus is said to have deserted Brahminabad at the time when the city was destroyed. All the details preserved, however, are so much mixed up with mythical incidents, that but little dependence can be placed upon them, and nearly all the circumstances mentioned are more or less open to dispute. It is questioned, for instance, whether Arur was ever situated on the Indus, and it is contended that Bakkar, a fortress on an island in the river opposite Rohri, and consequently in the channel now cut through the limestone range, existed before the ninth century. Certainly, the channel through the hills at Arur is very narrow, and it is possible that it was never traversed by the main stream of the river, though the configuration of the ground supports the hypothesis that some stream has cut through the hills at the spot. Again, it is contended that Sehwán, the ancient Sindomána, was always on the Indus, and that consequently the main stream of the river must have run in ancient times where it flows now. But, on the other hand, Alexander is said to have left the river, and marched to the neighbourhood of Larkhana, and thence to Sehwán, from which place he "marched back to the river."[3] It may be fairly concluded that important changes have taken place in the course of the river, without feeling certain that the precise nature of these changes has been correctly ascertained.

The accumulation of fluviatile deposits in the Indus plain, and the consequent elevation of the surface, is well seen in the neighbourhood of

[1] Cunningham's Ancient Geography, I, p. 257, 264, &c.;—Sind Gazetteer, pp. 23, 116, 123.
[2] Bellasis, Jour. Bombay, Br. R. A. S., V, pp. 413, 467.
[3] Arrian, Anabasis, VI, 16.

Umarkot, where, as has already been mentioned, the flood water from the Nara trickles through the sand-hills forming the limit of the Indus alluvium, and fills large hollows between the ridges of sand. The level of the bottom of these hollows must have been, in all probability, at least as high as the general surface of the Indus plain at no distant date.

During the floods, water leaves the Indus and its tributary, the Sutlej, as far up as Baháwalpur, and flows southward by the Eastern Nara, which must be regarded as a distributary, although its waters now seldom reach the sea. The true head of the delta, however, is generally considered to be a little above Hyderábád, where the Phuleli stream leaves the river.[1] The channels of the delta frequently change, more frequently perhaps than in the case of the Ganges. The sea-face is, in all probability, determined by marine currents, and it is improbable that any great change is likely to take place through the deposit of sediment.

The eastern part of the Indus delta now receives but little water from the river. It is said that a large area of country in the neighbourhood of the Kori mouth was depressed during the earthquake of 1819,[2] and that the great size of the Kori creek is due to the depression. A very large area north-west of the Kori creek is covered with salt, sometimes a foot or even more in thickness, deposited from sea water.

In the neighbourhood of the sea the soil is usually argillaceous and firm, but, in the upper part of the delta, the whole surface is composed of loose micaceous sand with but little clay, and the rivers consequently have unusual facilities for changing their channels. The littoral portion of the delta is so low, that a broad tract of country is always overflowed at spring tides, whilst the bottom of the sea in the neighbourhood of the coast is so shallow, and the slope outwards so gradual, that large vessels cannot, in many places, come within sight of the land. A tract of country of variable width, but in places several miles broad, along

[1] A very good description of the Indus delta has been given by Lieutenant T. G. Carless, Indian Navy (Selections from the Records of the Bombay Government, XVII, pp. 461-500). See also a memoir by Assistant Surgeon J. F. Heddle, ibid, p. 403. Lieutenant Carless' paper is also published in the Journal of the Royal Geographical Society, Vol. VIII, p. 328. For the ancient changes in the delta of the Indus, see also Cunningham's Ancient Geography, p. 283, &c.

[2] It is stated by Carless (Selections, Records, Bombay Government, XVII, p. 500) that the alluvial formations exposed on the bank of the Kori creek opposite Kotasir are, with the exception of the uppermost layers, broken up in confused masses, and inclined to the horizon at an angle of 30 or 40 degrees. The disturbance is attributed to the earthquake. It would be well, however, that the spot should be examined by an experienced geologist, the vagaries of oblique lamination in sands and silts, deposited by the strong currents of an estuary, being very likely to mislead any one unaccustomed to the peculiar appearance of these deposits.

the sea-face of the delta, is annually flooded by the rise of the river, the water being kept higher than it would otherwise be by the influence of the south-west monsoon.

The Ran of Cutch.—Reference was made a few pages back to the Ran (Runn) of Cutch, and it was pointed out that this tract of country is evidently an old marine gulf now silted up. A brief description of the area and its peculiarities may, however, be well added to the account of the Indus delta, which it adjoins to the eastward.

The Ran[1] consists of an immense marshy salt plain, scarcely above the sea-level, and stretching for 200 miles from east to west, and in places nearly 100 from north to south. From the south-eastern extremity a low alluvial tract, dividing Ahmedabad from Kattywar, and including an extensive brackish water marsh called the Nal, connects the Ran with the head of the Gulf of Cambay. A very trifling depression, probably not amounting to 50 feet, would convert Kattywar into an island, and even a smaller amount of sinking would suffice to isolate Cutch completely; indeed, it is now an island during the prevalence of the south-west monsoon, when the sea, raised by the wind, dams back the water brought into the Ran by the various rivers which drain into the flat from Rajpútána, Guzerat, and Cutch, in the same manner as the level of the creeks is raised in the Indus delta. At this time portions of the Ran are 7 feet under water, but the average depth does not exceed 5 feet. The inundation lasts from July to the end of November, and portions of the surface, especially a tract to the westward near Sindri, depressed by the earthquake of 1819, are constantly covered with water. Below this water there is, in places, a bed of salt, sometimes as much as 3 to 4 feet in thickness.

There can be little doubt that the Ran was a gulf of the sea within recent times; not only do the traditions of the country all agree with this view,[2] but the present condition of the surface, an immense flat of

[1] For a fuller description of the portion north of Cutch by Mr. Wynne, see Mem. G. S. I., IX, p. 14. See also Burnes, Travels in Bokhara, I, p. 316; Grant, Geological Transactions, Ser. 2, V, p. 318; Frere, Jour. R. Geog. Soc., XL, p. 181; Rogers, Q. J. G. S., 1870, p. 118.

[2] There is some historical evidence also. When Alexander the Great sailed down the Indus, he passed through the great eastern branch, then the main stream of the river, but now dry, to the Kori mouth. Near this mouth, he came to a great lake (Arrian, Anabasis, VI, 20). Mention is also made of a great lake-like expanse of water in this direction by some Mahammadan historians (Elliot, History of India, I, p. 125). These notices are taken from the anonymous paper already quoted in the Calcutta Review for 1874, CXVII, p. 18. Sir B. Frere also states, on apparently good traditional evidence, that Verawow, in Nagar Parkar, north-east of the Ran, was a seaport from 500 to 800 years since (Jour. R. G. S., XL, p. 195). No mention of any sea north of Cutch appears to have been made by the Chinese travellers of the seventh century (Cunningham, Ancient Geography of India, I, p. 302).

sandy mud, can only be explained by supposing that the tract is the site of an inlet, now silted up. The barren condition of the surface is due to flooding by salt water at one season, and hot dry weather at other times; the soil is consequently too salt to support even the vegetation, such as mangroves, which will grow in ordinary sea water. Unless further depression takes place, the surface must be gradually raised by the silt brought in by rivers, and the tracts which support vegetation must extend.

The depression of an area of 2,000 square miles around the fort of Sindri in the western part of the Ran, and the elevation of a tract, said to be 50 miles in length, and in places 16 miles across, at the time of the great earthquake of 1819, have been described so often,[1] that it appears unnecessary to repeat the account here. In this case the circumstance which enabled the changes of level to be accurately estimated was the very remarkable fact that the whole of the tract affected was very nearly at the sea-level, and so close to the sea, that it was flooded immediately. A further depression is said to have taken place in 1845 in the same neighbourhood.[2]

At first the effects of the depression in 1819 was to produce a great sheet of water, navigable by boats of some size; but this has gradually silted up, and Mr. Wynne, on visiting the ruins of Sindri in January 1869, found that the greater portion had been filled up to nearly the level of the Ran, and that but a small shallow pool remained around Sindri itself.

[1] An account is given in Lyell's Principles, Ed. 1868, II, pp. 97-104, and has been copied into many text books. For a very full description by Mr. Wynne, see Mem. G. S. I., IX, pp. 29-47. Mr. Wynne doubts whether the "Allah Bund," the supposed elevated tract, was really raised, and suggests, with much probability, that the appearance of elevation was due to the depression of the ground around Sindri, south of the "Allah Bund."

[2] Nelson, Q. J. G. S., 1846, p. 103. Before quitting the subject of the great alluvial region of Northern India, it may be as well to point out that by far the greater portion of the earthquakes, and especially of the more severe shocks felt in India, occur in the immediate neighbourhood of the Indo-Gangetic plain, and especially near the deltas of the great rivers. It is a subject worthy of further enquiry how far the earthquakes are connected with the pressure caused by the constant increase in the alluvial deposits, and the repeated recurrence of depressions. The earthquakes are, as a rule, felt much more severely on the rocky ground around the alluvial plain, than in the plain itself: when depression takes place, as in the case of Sindri in the Ran, the shock may be but slightly felt at the locality principally affected, although towns in Cutch, on rocky ground, at a distance of several miles, are thrown down; but this is in accordance with well-known laws.

CHAPTER XVIII.

PENINSULAR AREA.

POST-TERTIARY AND RECENT FORMATIONS—*continued.*

Alluvium of the East Coast — Estuarine shells in the alluvium — Alluvium of the West Coast of India — Bombay — Guzerat — Kattywar and Cutch — Littoral concrete, shelly grits of Bombay, Kattywar, &c. — Lake deposits — Soils — Red soil — Black soil, cotton soil or regur — Distribution — Origin — Peat — Blown sand — Indian desert — Other desert tracts — Sand denudation and striæ on rocks — Pot-holes in rivers — Prehistoric human implements — Stone — Palæolithic — Flakes or stone knives, and cores — Neolithic — Copper, silver, and bronze implements — Iron.

Alluvium of the East Coast.—Throughout the east coast of the Peninsula from the delta of the Ganges to the neighbourhood of Cape Comorin, with the exception of a few miles near Vizagapatam, there is a broad belt of alluvial deposits,[1] varying greatly in breadth, but nowhere exceeding about 50 miles. In places the hills approach the sea, leaving only a comparatively narrow belt of sandy foreshore, as south of the Chilka lake in Orissa, and again near Pondicherry, whilst near the mouths of the great rivers Máhánadi, Godávari, Krishna, Cauvery, &c., broad alluvial plains extend for many miles, and owing to the quantity of sediment deposited, there is actually a slight projection beyond the general coast line, although the strong currents, which sweep up and down the coast, prevent the rivers from extending their deltas seaward to any great extent.

There can be no reasonable doubt that the alluvial belt mentioned owes its existence, in a great measure, to the large quantity of detritus brought down by the rivers, for, as has been shewn in the introductory chapter, nearly the whole drainage of the Indian Peninsula runs eastward. It is difficult to judge whether the deposits would alone suffice to protect the older rocks from marine action. Probably they would, but the fringe of alluvial formations has unquestionably been raised since its deposition, for marine shells are found, in several places, many feet above the present range of the tide. The sea now in many localities gains upon the land, portions of the coast being occasionally washed away; but this action appears to be local, and there is no evidence of general marine denudation along the coast line.

[1] For details, see Mem. G. S. I., p. 274; IV, p. (247), and X, p. 15; also Newbold, Jour. Roy. As. Soc., VIII, p. 248.

To the northward the east coast alluvium joins the older alluvial deposits on the western side of the Ganges delta, and the two resemble each other closely in mineral characters. The coast alluvium consists chiefly of clays, with kankar, and, near the hills, pisolitic nodules of iron peroxide, the latter being in places sufficiently abundant to render the deposit a kind of laterite gravel. Gravels and sand also occur, frequently more or less mixed with ferruginous concretions, and there is in many localities an apparent passage between the ferruginous gravel of the alluvium and the low-level form of laterite.

The surface of the coast alluvium is usually quite flat near the sea and in the river deltas, but towards the hills it is more uneven, and evidently, from being at a higher level, the surface has undergone a considerable amount of denudation. In places this older alluvium rests upon the low-level laterite, which has been shewn, by the occurrence of palæolithic implements, to be itself of post-tertiary age, but in other places, as already noticed, there is an apparent tendency to a passage between the two. This may, of course, be due to the more gravelly forms of the laterite being washed down and re-arranged with the alluvial deposits.

Estuarine shells in the alluvium.—At Madras and Pondicherry, in several cases, shells belonging to recent species have been found in wells at depths of from 5 to 20 feet beneath the surface, or considerably above the present sea-level. The shells, as a rule, are estuarine forms, such as now live in the creeks and backwaters of the coast,[1] but in several cases true marine species have been found. About Madras the shells are found in beds of clay, and the following boring gives the whole thickness of the alluvial deposits[2]:—

	Ft.	In.
Sand and clay	3	0
Light-coloured sand and clay	1	0
Stiff clay	3	6
River sand	5	6
Black clay mixed with sand and shells	20	0
Blue clay with sand and lime and pieces of ironstone	12	6
Granite and quartz rubble	0	6
Clay and gravel mixed with broken granite, quartz, mica, &c.	9	0
TOTAL	55	0

[1] The following are the most characteristic species. They are seldom, if ever, found in the open sea, but they are always met with in backwaters, and at the mouths of rivers, and many of them occur in creeks of deltas near the sea.

Potamides telescopium.
P. fluviatilis.
Arca granosa.
Cytherea casta.
C. meretrix.
Ostrea, a large species.

[2] Newbold, l. c.

The site of this boring was at the Inland Custom-house, three-quarters of a mile from the sea. Beneath the depth mentioned crystalline rocks occurred. It is probable that the alluvium is in most places thicker than at Madras, but nothing more has been ascertained on this head. The subfossil shells near Madras are so abundant in places that they have been collected for burning into lime.

Farther south also, near Porto Novo, in the lower valley of the Vellaur,[1] a bed of estuarine shells is found above the present flood-level of the river, and consequently at a considerable height above the sea. Similar deposits of shells have also been noticed near Cuddalore and Tanjore.[2]

Another place where estuarine shells have been observed is close to the Chilka lake in Southern Orissa. The forms found were *Cytherea casta* and *Arca granosa*, and the deposit containing the shells is now at an elevation of from 20 to 30 feet above the level of the highest tides.

Alluvium of the west coast of India.—The differences in physical character between the east and west coast of India have already been noticed. Along the western shore of the Peninsula there is no such continuous plain of alluvium as on the east coast; the ground between the Sahyádri range and the sea, where not hilly, consists generally of a gentle slope towards the coast, composed of rock, covered in many places by laterite. The coast itself is rocky in parts, and the alluvial deposits are chiefly confined to the neighbourhood of the small streams, which run from the Western Gháts to the sea, or of the backwáters or lagoons which have been cut off by banks of sand along the coast. The backwaters are of considerable extent in Travancore and Malabar, but they are wanting farther north and on the coast of the Bombay Presidency; the alluvial valleys between the hills are unimportant south of Bombay itself, although they gradually increase in extent to the northward.

Bombay.—Alluvial plains, evidently of comparatively recent formation, connect the hills of Bombay and Salsette Island, a few creeks alone remaining to shew the position of the marine channels which formerly existed. Farther north these plains gradually increase in extent, until they merge into the alluvial flat of Guzerat.

At Bombay the alluvial deposits[3] consist of blue and yellowish-brown clay; the former varies in thickness from a few inches to several feet, its upper surface being at present about a foot or two below high-water level; it is very salt, and contains small grains and nodules of kankar, and

[1] H. F. Blanford: Mem. G. S. I., IV, p. 192.

[2] King and Foote: ib., p. (254.)

[3] Buist: Trans. Bombay Geo. Soc., X, p. 181;—Carter: Jour. Bombay Br. R. A. S., IV, p. 204.

occasionally plates of gypsum; it is frequently penetrated by mangrove roots, which are usually riddled by *Teredo* borings, just as in the mud of tidal creeks, and at one spot large masses of oysters have been found in it. The yellowish-brown clay appears to be the older of the two deposits; its surface is frequently above the sea-level, it abounds in larger masses of kankar, and it has occasionally yielded estuarine shells, *Placuna, Ostrea,* &c. That these alluvial deposits are estuarine, and precisely similar to the mud now deposited in the creeks and backwaters of the coast, or on the shores of Bombay harbour, is shewn by the similarity of mineral character and by the organic remains, both vegetable and animal, found in the clay.

It is evident that Bombay harbour is the last remaining inlet out of many which formerly indented the Bombay coast, and that this harbour is gradually silting up and being converted into dry land. The process, however, is probably slow, and it may be ages before its progress is such as to affect the trade of Bombay, but, unless depression takes place in the area, or means are devised for checking the deposition of mud, there can be no question of the ultimate result. Except at Bombay, little has been recorded concerning the alluvium of the western coast south of Damán, and that little presents no features of interest.

Guzerat.—In the neighbourhood of the rivers Tapti and Narbada, which, unlike the other streams draining the Peninsula, flow to the west coast, there is, however, near the sea, a broad and fertile alluvial plain,[1] which, in some of its features, resembles the alluvium of the east coast. Commencing to the southward near Damán, this plain covers the greater portion of the Surat, Broach, and Ahmedabad districts, and continues as far as the Ran, where it joins the area of recent deposits connected with the Indus valley. Near Surat this plain is about 30 miles in breadth, and near Baroda it is 60 miles wide.

The alluvium of eastern Guzerat consists of brown clays, with kankar, resting upon sands and sandy clays, with occasional gravels. The surface is covered with black soil to the southward, though not in the district of Ahmedabad, and is frequently horizontal over considerable areas, but in parts of the country the ground is undulating, evidently in consequence of having been denuded by rain-action. The deposits appear to have been chiefly estuarine or marine, and have probably been raised, as on the east coast, but no fossils have been found. The Gulf of Cambay is said to be gradually silting up, and there can be very little doubt that it was formerly part of a broad inlet leading from the Ran, then an inland sea, to the ocean, and that the remainder of the inlet

[1] Mem. G. S. I., VI, p. (233);—Rec. G. S. I., I, p. 30; VIII, p. 49.

has been converted into the alluvial plains of Ahmedabad, Broach, Surat, and north-eastern Kattywar.

Kattywar and Cutch.—In North-Eastern Kattywar, on the borders of the Ran, there is a large alluvial tract[1] continuous with the alluvium of Ahmedabad, and similar in character. Between Kattywar and Ahmedabad, in the line of depression between the head of the Gulf of Cambay and the Ran, there still exists a large shallow lake of brackish water, called the Nal, about 20 miles in length and 3 or 4 broad. In the neighbourhood of this marsh, shells of a form of *Cerithium* (probably *Potamides telescopium* or *P. fluviatilis*) are found, shewing that estuarine conditions have prevailed at no distant period, and tending to confirm the probability that the depression between Kattywar and Ahmedabad is an old marine inlet, silted up in recent times. The distribution of black soil in the neighbourhood of the Nal will be noticed presently.

Along the south coast of Kattywar there is very little alluvium, its place being taken by a calcareous grit, with marine shells, which is evidently of late formation.[2] A glance at the map will shew that this coast is exposed to the full action of the currents, which sweep along the shores of the Peninsula, so that it is unlikely that any accumulation of sediment would take place. The north-western coast of Kattywar on the borders of the Gulf of Cutch does not appear to have been described by any geologist; there is probably a belt of alluvium, as there is throughout the coast-line of Cutch,[3] where this belt is from 3 to 10 miles broad, there being only one place where rocks come down to the shore. This is in the Gulf of Cutch. The alluvial plain of Cutch consists of a brown loam, resting upon mottled clay, with kankar and grains of quartz.

Littoral concrete: shelly grits of Bombay, Kattywar, &c.—An agglutinated calcareous shelly grit is found, a little raised above the sea-level, in several places on the west coast of India. This deposit, which is called "littoral concrete" by Dr. Buist,[4] consists of shells, corals, pebbles, and sand, cemented together more or less thoroughly by carbonate of lime, and sufficiently compact in places to be employed as an inferior kind of building stone. The best known locality is in Bombay island, where the shelly grit forms the flat ground of the Esplanade and part of the surface on which the fort was built; the same deposit is also

[1] Rogers: Q. J. C. S., 1870, p. 118.
[2] MS. notes by Mr. Theobald.
[3] Wynne: Mem. G. S. I., IX, p. 81.
[4] Trans. Bombay Geog. Soc., X, p. 179; see also Carter; Jour. Bom. Br. R. A. S., IV, p. 206.

found at Mahim and other places in the island, resting sometimes upon rock, but more often upon the blue alluvial clay, described a few pages back. The same formation is found to the southward at Malwán,[1] and northward here and there as far as Damán, where it was observed by Mr. Wynne, apparently in process of formation.[2] Near Balsár, a little north of Damán, the littoral concrete was observed to be stratified, the strata dipping at a low angle towards the sea.

In Western Kattywar the same formation is much more widely developed. It here assumes the character of an earthy calcareous grit; it is usually of a dark ashy colour, and contains marine shells and corals; occasionally it attains a thickness of 60 feet, and it rests unconformably on the denuded surface of the "Miliolite."[3] The fossils found in the calcareous grit, so far as is known, are all species now living on the neighbouring coast, but no thorough comparison has ever been made.

There can be very little doubt that the shelly calcareous grits of the Bombay and Kattywar coast are truly marine, not estuarine, and that they are the result of a littoral accumulation of the sand and pebbles found on the shore, together with marine shells and corals. The beds may have originally been sand spits or beach deposits, very little, if at all, above high-water mark, and consolidated by the cementing action of carbonate of lime after being raised. In any case there appears to be evidence of a rise in the land, trifling at Bombay, but greater in Kattywar.

Lake deposits.—Indications of local deposits, supposed to have been formed in lakes, have been noticed on the Nilgiri hills of Southern India[4] and in the Southern Máhratta country,[5] and have been supposed to indicate changes of level. No fossils have been found in these deposits, nor does the evidence in either case amount to clear proof of the former existence of lacustrine conditions, although the probabilities are in favour of this view.

Soils.—It would be beyond the scope of the present work to enter into the question of Indian soils. Consisting as they do of the surface of the ground altered by the action of the air and rain, by impregnation with organic matter and the results of agricultural processes, they necessarily vary with every difference in the underlying formation, whether it be one of the older rocks or of the more recent unconsolidated deposits. There are, however, two forms of superficial formations which have received repeated notice in Indian geological works, and to which a few remarks must be devoted, and one of the two, the

[1] Mem. G. S. I., XII, p. 243.
[2] Rec. G. S. I., I, p. 32.
[3] See p. 342.
[4] H. F. Blanford: Mem. G. S. I., I, p. 243.
[5] Foote: Mem. G. S. I., XII, p. 228.

regur or black soil, is a very remarkable substance. The red soil also requires notice, because it has been so frequently mentioned in geological treatises.

Soils might very well be classed into two great sub-divisions:—upland soil resulting from the decomposition of rock *in situ*,—and alluvial soil, due to the surface alteration of river and flood deposits.[1] It would of course be difficult, if not impossible, to draw an exact line between the two, for the alluvial soil, on the margin of every valley, passes by insensible gradations into the upland soil of the hill slopes. The soils of the great Indian river plains belong of course to the alluvial sub-division, whilst the soil found on the plateaus of the Deccan and the undulating country of Southern India is to a large extent due to the decomposition of rock *in situ*, although alluvial soil of one kind or another is found in all hollows, and occupies large areas in the river valleys. Both "black soil" and "red soil" occur in large quantities in both sub-divisions; but the fine alluvial soil of the Indo-Gangetic plain is very different from either of the forms of surface prevalent in the Peninsula. Where the surface of the Ganges valley has undergone

[1] The Indian Peninsula is so vast, and the variations in climate in different portions so great, that the ingredients of the soil are only one amongst many factors determining the agricultural products of the country. The other principal elements are temperature and rainfall. Very roughly indeed, India might be divided into three agricultural regions:

I. Extra-tropical India; the wheat region. This consists of the great plains of Northern India in which the rainfall is moderate or small, and the winter temperature comparatively low. The region almost corresponds with that lying north of the January isotherm of 65°. The principal grains are wheat and barley.

II.—The damper portions of tropical India, the rice country. This comprises all Bengal proper, and all the region north of the Krishna from the Bay of Bengal to the edge of the trap country in the Deccan, together with the coasts and delta lands of Southern India. The principal grain is rice.

III.—The drier parts of tropical India and all the black soil country; the millet region. Besides the whole Deccan trap area, with the exception of the western coast, this comprises all the black soil tracts of Southern India, and a very large portion of the undulating red soil country. The principal grains are jawári or cholam (*Holcus sorghum*) and bájri or kambú (*Holcus spica*).

Of course, these divisions are not clearly separated from each other. The important point in connexion with the geology is the fact that nowhere in the black soil regions, nor on any of the soils derived from the Deccan traps, except in a small strip of country, with a heavy rainfall, near the western coast, is rice the staple grain of the country. In the Central Provinces, especially in the neighbourhood of Nágpúr, the difference between the agriculture of the trap country, with fields of millet, pulses of several kinds, cotton, linseed, &c., produced without irrigation, and the cultivated area of the sandstone and metamorphic rocks, where little is seen growing, except rice and sugar irrigated from large tanks, is as marked as the distinction between the rocks themselves. The wild vegetation of the two formations is as different as the cultivated grains. The whole distinction is of course due to the difference in the soils derived from different rocks.

but little change from agriculture, and where it is not impregnated by organic matter, it consists of a very fine, light-coloured argillaceous loam, varying from pale grey to pale brown in colour, and becoming very hard when thoroughly dry.

Red soil.—The somewhat ferruginous soils common on the surface of many Indian rocks, and especially of the metamorphic formations, would probably never have attracted much attention but for the contrast they present in appearance to the black soil. They have only been noticed, as a rule, in papers relating to the western and southern portions of the Peninsula, the black soil country. The commonest form of red soil is a sandy clay, coloured red by iron peroxide, and either derived from the decomposition of rock *in situ* or from the same products of decomposition washed to a lower elevation by rain. The term "red soil" is, however, frequently used in a very vague sense, apparently to distinguish such soils as are not black, and hence many alluvial soils may be comprehended under the general term. In very many cases, too, the term "red soil" appears to have been applied in Southern India to thick alluvial beds of sand or sandy clays, which are in fact ordinary river or rain-wash deposits.

Black soil, cotton soil, or regur (regad).—The regur of Peninsular India,[1] called black soil from its colour, and cotton soil from its suitability to the cultivation of cotton, occupies the surface of a very large portion of the country, and Newbold considers that at least one-third of Southern India is covered by it. The name regur is a corruption of the Telugu *regada*, or of cognate words in affined languages.

Regur, in its most characteristic form, is a fine dark soil, which varies greatly in colour, in consistence, and in fertility, but preserves the constant characters of being highly argillaceous and somewhat calcareous, of becoming highly adhesive when wetted, (a fact of which any one who has to traverse a black soil country after a shower of rain

[1] The following are some of the principal writers who have described regur:

Christie: Edinburgh New Phil. Jour., VI, p. 119 (1829); VII, p. 50 (1829); Madras Jour. Lit. Sci., IV. p. 469 (1836).

Voysey: J. A. S. B., II, pp. 303, 397 (1833).

Newbold: Proc. Roy. Soc., IV, p. 54 (1838); J. A. S. B., XIII, p. 987 (1844); XIV, pp. 229, 270 (1845); Jour. Roy. As. Soc., VIII, p. 252 (1846).

Hislop: Jour. Bombay Br. R. A. S., V, p. 61 (1853).

Carter: Jour. Bombay Br. R. A. S., V, p. 329 (1854).

Theobald: Mem. G. S. I., II, p. 298 (1860); X, p. (229) (1873).

H. F. Blanford: Mem. G. S. I., IV, p. 183, (1862).

King and Foote: Mem. G. S. I., IV., p. (352) (1864).

Oldham: Rec. G. S. I., IV., p. 80 (1871).

Foote: Mem. G. S. I., XII, p. 251 (1876).

See also Mem. G. S. I., VI, p. (235) (1869); Rec. G. S. I., VIII, p. 59 (1875).

becomes fully aware,) and of expanding and contracting to an unusual extent under the respective influences of moisture and dryness. Hence in the dry season the surface is seamed with broad and deep cracks, often 5 or 6 inches across and several feet deep. Like all argillaceous soils, regur retains water, and consequently requires less irrigation than more sandy ground; indeed, as a rule, in the Western Deccan, Nágpúr, and Hyderábád, black soil is never irrigated at all. When dry, it usually breaks up into small fragments; on being moistened with water, it gives out an argillaceous odour. It is said to fuse, when strongly heated, into a glassy mass, but, as might be expected, this is not invariably the case, and is probably dependent on the proportions of iron and lime present.

The chemical composition of regur has not received much attention. From the few and partial analyses[1] which have been made, the proportions of iron, lime, and magnesia seem to vary, and there appears

[1] The following are the analyses. In the first, by Dr. Macleod, and published by Captain Newbold, Jour. Roy. As. Soc., VIII, p. 254, a complete analysis of a dried sample appears to have been made. In the other analyses by Mr. Tween, (Mem. G. S. I., IV, p. (361),) undried soil was used, and the component parts were only determined in the soluble portion In neither case is it stated how the analyses were made, nor which ingredients were determined by loss:—

Silica	48·2	The locality from which this soil was obtained is not stated.
Alumina	20·3	
Carbonate of lime	16·0	
Carbonate of magnesia	10·2	
Oxide of iron	1·0	
Water and extractive	4·3	
	100·0	

	A		B		C	D	E
	1	2	1	2			
Insoluble	62·7	47·61	62·8	63·7	68·61	57·91	61·80
Organic matter	9·2	8·4	9·	8·7	7·2	8·7	7·65
Water	8·4	7·6	8·2	6·5	9·4	9·9	7·35
Oxide of iron	11·	15·9	10·9	11·4	6 76	4·36	5·7
Alumina	7·5	8·6	7·6	8·4	5·81	8·75	7·67
Carbonate of lime	1·2	11·89	1·5	1·3	1·57	9·28	8·53
	100·	100·	100·	100·	99·35	98·90	98·70

"The residue in all consisted chiefly of magnesia and alkali; in A1, B1, and B2, there were traces of sulphuric acid.

"A and B were from near Seoni, C from Indore, D from Barwáni, and E from Burhanpur: (Seoni and Barwáni are in the Narbada valley, and Burhanpur in the Tapti).

"A1, A2, represent the surface soil and subsoil taken from the same locality, A1 being the surface, A2 from 5 feet below surface. The two marked B1, B2, are, in like manner, the soil and subsoil (3 feet deep) from one locality, while C, D, and E are the soils taken from only a few inches below the surface. B1 is considered the best quality of soil."

always to be a considerable quantity of organic matter combined. The black colour appears to be due either to the carbonaceous elements of the soil, or to organic salts of iron, but the tint varies much, being frequently brownish and sometimes grey.

Christie made some experiments to determine the absorbent power of regur. He first dried a portion at a temperature nearly sufficient to char paper; he then exposed to the atmosphere of a moderately damp apartment 2615·6 grains of the dried soil, and found after a few days that it had gained 147·1 grains. He then exposed the same sample to an atmosphere saturated with moisture, and found that the weight increased daily, till the end of a few weeks, when it was found to be 2828·4 grains. The soil had, therefore, gained 212·8 grains, or about 8 per cent.

As a rule, the purest beds of regur contain no pebbles, although this soil usually abounds in kankar. Fragments of chalcedony or zeolite are, however, often found in the black soil, where it is derived from the decomposition of basalt, and in Southern India regur occasionally contains debris of the metamorphic rocks, sandstone or limestone, on which it rests.

Where uncultivated, black soil plains usually support but few trees, and those, as a rule, of no great size, but the principal product is grass, commonly growing to a height of 3 to 4 feet, but sometimes considerably higher. The growth of grass on the uncultivated plains of India is, however, greatly promoted, and the trees injured or killed by the universal practice of burning the grass annually in the dry season, so that it is probable that, if left to themselves, the plains of black soil would support forest.

The fertility of this soil is so great, that some of the black soil plains are said to have produced crops for 2,000 years without manure, without having been left fallow, and without irrigation. On the other hand, some varieties of black soil, occurring near the coast of Southern India, are comparatively infertile.

The typical appearance is only presented by this soil near the surface of the ground; if the regur is more than about 6 to 10 feet deep, it usually passes down into brown clay with kankar. It is never, except where it has been carried down and rearranged as a stream deposit, met with at any depth beneath the surface.

Distribution.—The distribution of black soil in the Indian Peninsula is of some importance, because it affords a clue to the origin of the formation. Regur is found everywhere on the plains of the Deccan trap country, except in the neighbourhood of the coast. A very similar

soil is found locally in the basaltic Rájmahál hills, but, with this exception, nothing of the kind appears to be known in Bengal or the neighbouring provinces. In Southern India, however, tracts of black soil are found scattered throughout the valley of the Krishna, and occupying the lower plains and flats of Coimbatore, Madura, Salem, Tanjore, Ramnád, and Tinnevelly. There is but little on the Mysore plateau. Some occurs on portions of the coast plain on the eastern shore of the Peninsula, and the great alluvial flat of Surat and Broach in Eastern Guzerat consists of this soil. The soils of Ahmedabad are light-coloured, but regur occupies the surface of the depression lying between Ahmedabad and Kattywar, and connecting the head of the Gulf of Cambay with the Ran of Cutch.[1]

Origin.—In many cases there cannot be a question that regur is simply derived from basalt by surface decompositon, and it is not surprising that numerous observers, from Christie and Voysey to Carter and Theobald, should have contended, and should still contend, that all cotton soil is derived from disintegrated trap rocks. Throughout the immense Deccan trap area, the passage from decomposed basalt into regur may be seen in thousands of sections, and all the alluvial valleys, most of which contain black soil, are filled with deposits derived from the disintegration of basaltic rocks. More than this: over enormous areas the boundary of the trap is approximately the boundary of the black soil; where the latter is found beyond the trap boundary, volcanic rocks may very probably have existed formerly, and have disappeared through disintegration, or the soil has been washed down from the neighbouring trap hills. This is admirably seen around Nágpúr and Chánda in the Central Provinces; everywhere upon the trap regur occurs; a few miles to the eastward, upon the metamorphic rocks, it is never seen, except where there is reason to suppose it has been transported, as in the alluvial flats of rivers, like the Godávari, running from the trap country. Again, whilst nothing resembling regur is found in the metamorphic region of Bengal, Behar, Orissa, Chutia Nágpúr, Chhattísgarh, and the neighbouring provinces, soils undistinguishable from those of the Deccan traps are found in the basaltic Rájmahál hills, and a similar formation has also been observed in Pegu,[2] derived from the decomposition of basalt. It has been urged that basalt may have been more widely spread in Southern India than is now the case, and that, where none is now found, its disappearance is due to its having been converted, by disintegration, into regur.

[1] Rogers: Q. J. G. S., 1870, p. 118. | [2] Theobald: Mem. G. S. I., X, p. (229).

This view cannot, however, be conceded. In the first place, as was shewn by Newbold, basalt generally disintegrates into a reddish soil, quite different from regur in character. This reddish soil may be seen in places passing into regur, but, as a rule, the black soil is confined to the flatter ground at the bottom of the valleys, or on flat hill tops, the brown or red soil occupying the slopes. Again, the masses of black soil in the valleys of the Godávari and Krishna might be due to the alluvial deposits having been derived from the trap rocks, through which both rivers flow in the upper part of their course, but hundreds of square miles in the basins of the Pennár, Palár, Cauvery, and other rivers still farther to the south are composed of precisely similar regur to that of the trap area. There is no reason for supposing that the Deccan trap ever extended to the valleys of the rivers named, nor can there be any reasonable doubt that the alluvial flats contained in these valleys are mainly formed from the detritus of metamorphic rocks.

Captain Newbold considered [1] all regur to be of subaqueous origin in India, and compared it to the deposits in tanks, and to the mud of the Nile. Mr. H. F. Blanford suggested [2] that the cotton soil of Trichinopoly had accumulated in lagoons or backwaters near the sea, and he shewed that in one place near Pondicherry typical regur was actually being formed in a nearly dry lagoon separated from the sea by a sand spit. Messrs. King and Foote, on the other hand, considered [3] it more probable that the Trichinopoly regur was a fresh-water deposit accumulated in marshes. It has since been shewn [4] that a complete passage takes place in the neighbourhood of Surat between the deposits formed in tidal estuaries and the regur of the surrounding country, and it appears probable that much of the black soil of Eastern Guzerat may have been originally a marine or estuarine (brackish water) formation. On the other hand, Hislop [5] objected to the theory of formation by deposition in water, and he appears to have been the first to suggest that regur may really be of subaërial origin and due to the impregnation of certain argillaceous soils by organic matter. This appears to be the most probable theory; there can be no doubt that some forms of regur originate from the decomposition of basalt *in situ*, others from the disintegration of other argillaceous rocks, whilst other varieties again were originally alluvial clays formed in river valleys, or deposited in fresh-water marshes, estuarine flats, or salt-water lagoons. The essential character of a dark colour appears due in all cases to the admixture of organic matter, and perhaps the presence of

[1] Jour. R. A. S., VIII, p. 256.
[2] Mem. G. S. I., IV, p. 191.
[3] Mem. G. S. I., IV, p. (357).
[4] Rec. G. S. I., VIII, p. 50.
[5] Jour. Bombay Br. R. A. S., V, p. 61.

a small quantity of iron. It is far from improbable that most of the black soil flats of India were at one time covered with luxuriant forest, for when the vegetation was not annually exposed to the effects of fire, the trees may have attained far greater dimensions than they do now. The increased dampness of the soil, the protection from denudation by rain, and the supply of decomposing vegetable matter may have contributed to the formation of themore fertile forms of regur. That the process of regur formation is purely superficial, and that it is due to surface action of a past time, is well seen in many of the regur plains with a slightly undulating contour. In such places, where the wash of rain has swept away the surface soil on the sides of hollows, the earth is brown; on the flats above, it is black, because the superficial layer has not been washed away; the black soil, however, washed from the sides of the hollows, has frequently accum ulated towards the lower portion of them.

The abrupt termination of regur in places at the edge of the trap country is simply due to the change from an argillaceous soil to a sandy one. The basalt appears generally to decompose into a highly aluminous substance; the metamorphic rocks, on the other hand, produce sand to a large extent. At the same time, it should be stated that it is not quite clear why argillaceous deposits should have become regur in Southern India, whilst nothing of the kind is known in Bengal, except in the basaltic region of the Rájmahál hills. A dark-coloured soil certainly forms in the marshes of Eastern India; but it has not the character of regur, and no cotton soil has been noticed in the dense forests of Chutia Nágpúr and Bastar, nor, except on the surface of basalt, in the forest-clad plains of Burma. It is doubtful whether true regur occurs on the Malabar coast between Bombay and Cape Comorin, and the marshy soils on the top of the Sahyádri range do not form cotton soil. The black soil plains appear to be almost confined to those parts of India which have a moderate rainfall, not exceeding about 50 inches; but it is impossible to say whether this is a necessary condition.

It may then be stated that regur has been shewn on fairly trustworthy evidence to result from the impregnation of certain argillaceous formations with organic matter, but that the process which has taken place is imperfectly understood, and that some peculiarities in distribution yet require explanation.

Peat.—True peat forms in the hollows on the Nilgiris and some of the other mountains in Southern India, such as the Shivarais,[1] at

[1] Foote: Mem. G. S. I., XII, p. 252.

elevations above 4,000 feet, and its formation is due, as in temperate climates, to the growth and decomposition of a moss. In the marshes of the Gangetic delta an inferior kind of peat is also formed by the decomposition of various aquatic plants, and especially of wild rice.[1] The peat-like beds found so widely distributed in the neighbourhood of Calcutta at a little depth below the surface appear to be derived from the decomposition of forest vegetation.[2] A somewhat similar substance has been obtained from beneath a marsh in Oudh.[3]

Blown sand.—Sand drifted by the wind forms low hillocks on many parts of the Indian coast. Reference has already been made to the parallel ridges of sand-hills along the shore of Orissa.[4] A similar tract of blown sand is found north of Orissa in the Midnapur district, and southwards at intervals throughout the whole of the east coast.[5] The sand is, of course, derived from the sea-shore and blown up into ridges at right angles to the prevailing wind, with their longer slope to windward and a shorter and steeper surface to leeward. Smaller patches of sand are sometimes found on the banks of backwaters. The sand-hills frequently extend for 2 or 3 miles inland from the coast, and in such cases the inner ridges are covered with a peculiar vegetation, amongst which the cashew-nut tree (*Anacardium occidentale*) and a screw-pine (*Pandanus*) are conspicuous, and in some cases between the parallel ridges coinciding in direction with the coast the ground is flat, and even occasionally, as in parts of Midnapur, marshy. In the latter case, it is probable that a lagoon has existed, which has been gradually dried up, the origin of the lagoon being due to the formation of a sand spit outside it. As already noticed, the existence of several parallel sand ridges probably indicates a rise of land, each ridge coinciding with a former coast line.

On the Malabar coast, sand dunes are equally common, and, by accumulating on spits of sand, they contribute greatly to the formation of lagoons or backwaters.[6] In the northern portion of the western coast about Bombay no sand-hills have been noticed, probably because the detritus from the trap rocks does not form a suitable material, but farther north again, in Surat and Broach,[7] in portions of Kattywar, and

[1] J. A. S. B., XXIII, 1854, p. 400.
[2] See p. 400.
[3] Proc. A. S. B., 1865, p. 85.
[4] Mem. G. S. I., I, p. 275.
[5] Newbold: Jour. Roy. As. Soc., VIII, p. 268;—King and Foote: Mem G. S. I., IV, p. (249);—Foote: ib., X, p. 12.
[6] Newbold: Jour. Roy. As. Soc., VIII, p. 268.
[7] Mem. G. S. I., VI, p. (235); IX, p. 82.

in Cutch, blown sand occupies more or less ground in many places in the neighbourhood of the shore.

Sand dunes in India are not confined to the sea-coast, but are frequently found on the banks of rivers. One example has already been mentioned, the Bhúr land of the Punjab,[1] and the accumulation of blown sand on river banks is of common occurrence on many of the peninsular rivers, such as the Godávari, Krishna, and Cauvery.[2] In some instances noticed by Newbold,[3] villages have been buried by the sand blown from the river beds during the dry season. In fact, the study of the action of the wind and its effect in transporting detritus of all kinds cannot be said to have received much attention hitherto, but in the drier parts of India the amount of dust and sand transported by the atmosphere must be very great.

Indian desert.—By far the most important accumulation of blown sand in India is, however, between Sind and Rájputána, in the tract known as the great Indian desert.[4] The name conveys a somewhat imperfect idea, because the region in question is neither absolutely barren nor uninhabited; it is covered with shrubs and bushes in general, and small trees are found in places, whilst villages are scattered throughout, and immense herds of camels, cattle, goats and sheep are pastured. The desert is, in fact, a great sandy tract without any streams of water, and a large portion of the surface consists of blown sand.

Besides the isolated sand-hills scattered over the region, there are some tracts, in particular, in which the whole area appears to consist of sand dunes. One of these tracts, known as the Thar (Thurr), extends along the edge of the Indus alluvium from the neighbourhood of the Ran of Cutch to north-east of Rohri, and probably farther still to the northward, towards Baháwalpur. This tract is about 60 miles across near Umarkot, and 50 miles east of Rohri. The sand-hills are arranged in regular parallel, or nearly parallel, ridges running north-east and south-west near Umarkot, whilst to the north their direction is from south-south-west to north-north-east. Farther south than Umarkot and near the Ran, the general direction of the sand ridges is said to be nearly east and west, and they are much higher than they are elsewhere, some having an elevation of as much as 400 or 500 feet.[5]

Another great tract of sand-hills more to the eastward extends north-north-east from the neighbourhood of the Ran along the western side of

[1] P. 404.
[2] King and Foote: Mem. G. S. I., IV, p. (249).
[3] Jour. Roy. As. Soc., VIII, p. 269.
[4] J. A. S. B., XLV, 1876, pt. 2, p. 86; Records G. S. I., X, p. 20.
Sir H. B. E. Frere: Jour. Roy. Geog. Soc., 1870, vol. XL, p. 200.

the Luni river, towards Bikanir. Between Jodhpúr and Pokarn, this belt of sand dunes is about 40 miles broad. It is probably connected with the western tract by the east and west ridges already mentioned in the neighbourhood of the Ran. The sand-hills in the eastern tract are lower than to the westward, and they are not in such regular ridges.

Throughout the central portion of the desert around Bálmir and Jesalmir the ground is higher, and there are rocky hills. There is still a great quantity of drifted sand scattered over the surface, but sand-hills are few and of small size. The sandy region also extends to the eastward as far as the Arvali (Aravully or Aruvelly) range, and even beyond in places. To the northward blown sand is found throughout Baháwalpur and Bikanir as far as the neighbourhood of the Jumna.

The general direction of the sand-drift is evidently from south-west and south-south-west, the direction from which strong winds blow in the hot season, May, June, and July. At other times of the year the winds are light and variable, but in the months mentioned a steady breeze, sometimes becoming violent, sets in from the quarter named. It is a well-known fact, explained in all elementary works,[1] that sand or any other substance, moved along the surface by air or water, arranges itself in ridges at right angles to the current, with a lower slope towards the direction from which the moving power comes—to windward, in the case of air,—and a steeper slope in the opposite direction or to leeward. The "rippling" or current marking on the surface of sandstone, &c., is a familiar example, and so are the small ridges produced on the surface of dry sand by the wind. The long slope to windward varies in the angle of dip, the steep slope to leeward is that naturally assumed by the sand when blown over the crest of the ridge.

In general throughout the desert the sand-hills, whatever be their form, have a steep slope to the north-east, and a lower slope to the south-west, and the sand in many places, as west of Bálmir, accumulates in large quantities on the north-east or leeward side of the rocky hills. Even in the long parallel south-west and north-east ridges of the Thar, which are often from a quarter of a mile to half a mile across and extend for many miles, and in which there is no constant distinction between the slopes on the two sides, abrupt terminations with a steep slope to the north-east are frequently seen. It is evident that the enormous quantity of sand in the desert region is derived from the south-west, and that it has been transported by the strong winds of the hot season. Here two rather different questions arise: the source of the sand, and the reason

[1] See Lyell, Principles, (Ed. 1867) I, p. 516; De la Beche, Geological Observer, p. 59; Marsh, Man and Nature, pp. 471-483, &c.

why the great sand ridges of the Thar are parallel to the direction of the prevailing winds instead of at right angles to it.

It should be noted that many of the sand-hills are evidently of great antiquity; they often shew evidence of denudation from the action of rain, and in places they are worn into ravines several feet in depth. When the small rainfall of the desert region[1] is taken into consideration, it is evident that a long series of years must be required for ravines to be cut in the sand, since it is only in exceptionally heavy showers that any rain can run off so porous a surface. The great age of the sand-hills is also attested, though in a minor degree, by the evidence of the inhabitants.

It appears difficult to believe that all the sand found in the desert can have been derived from the Indus. The surface of the Ran at present is too muddy to furnish any large supply. The sand consists of well-rounded quartz grains mixed with smaller quantities of felspar and hornblend, and is undistinguishable from the sand of the sea-coast. That found in the bed of the Indus is also very similar in character. The most probable theory appears to be that the Ran of Cutch and the lower portion of the Indus valley have been, as has already been shewn to be probable on other grounds, occupied by the sea in post-tertiary times, and that the sand of the desert was derived from the shore. The most sandy tracts, as has also been shewn, are on the edge of the Indus valley, along the northern margin of the Ran, and along the depression of the Lúni valley, and these portions of the country were all probably situated on the coast. The form of the rocky hills around Bálmir and Jesalmir shews that they have been shaped by subaërial, not by marine, denudation, and it is probable that the central portion of the desert was land, whilst the Indus valley, the Ran, and the Lúni valley were occupied by sea.

The other difficulty, that of accounting for the direction of the sand ridges in the Thar, is greater. The most probable explanation appears to be that the hollows between the ridges are due to denudation by the wind, and that the tract was originally much more thickly covered by sand than it now is.[2]

The accumulation of sand in the desert region is evidently due to the low rainfall and to the consequent absence of streams, the effect being intensified by the accumulation of sand and the porous nature of the resulting surface. In other parts of India the sand blown from river

[1] The amount is only known at a few localities. The average rainfall at Karáchi is 7·03 inches; Umarkot, 11·8; Mooltan, 6·21; Sirsa, about the same. The rainfall at Jesalmir and Jodhpúr is unknown. At Deesa it is much greater, 34·57 inches; but the quantity increases rapidly to the eastward.

[2] For a full discussion of this subject, see the paper already quoted on the Indian desert, J. A. S. B., 1876, Vol. XLV, pt. 2, p. 97.

channels or the sea-coast is either driven by the wind into other river channels, or it is swept into them again by rain. There are sand-hills in abundance in the alluvial plain of the Indus, but they attain no great size, because the sand is always swept sooner or later into some stream, by which it is carried away towards the sea. As, owing to the increased rainfall, streams appear in Rajpútána, or to the northward, in the Ganges valley, the sand-hills disappear.

Other desert tracts.—Besides the occasional sand-hills of the Indus valley in Sind, there are some much larger tracts in the Panjáb, repeating, on a smaller scale, the phenomena of the Thar and the Rajpútána desert. The most important of these is in the Sind Ságar Doab between the Indus and Jhelum, but there is a barren tract in the Rachna Doab between the Chenáb and Rávi, and sand-hills occur in places also in the Bári Doab between the Rávi and Sutlej.

Sand denudation and striæ on rocks.—In connexion with the sand drift, the marks produced by the combined action of the wind and sand on rocks may be noticed. These are very conspicuous in places on the jurassic limestones of Jesalmir, and on the nummulitic limestones of Sind. The surface of the limestone on the plateaus close to Jesalmir is everywhere scored with grooves and striæ, striking about N. 35° E., the direction of the strong sand-transporting winds of the hot season. The resemblance to glacial markings is very great, but there is an absence of the polished surface, characteristic of ice action.

Pot-holes in river-beds.—It would be unnecessary to mention this common form of erosion but for the circumstance that it has been [1] supposed that no instances have been noticed in India, and it has hence been inferred that the phenomena are rare. On the contrary, as might be expected, pot-holes, or giants' cauldrons, are not only excessively common in the beds of Indian rivers, but, owing to the alternation of wet and dry seasons, and the consequent exposure of the river-beds to floods at one period of the year, whilst the channels remain nearly dry at other seasons, there are in India unusual facilities for studying the effects, upon rocks, of water in violent motion. Pot-holes consequently abound in the beds of all streams and rivers traversing sandstone, limestone, or any other rock of fairly homogeneous composition, including basalt and other varieties of trap, many forms of metamorphic rocks, and even quartzite. The abundance of these marks of erosion, indeed, caused them to be noticed in Southern India many years since; several were described by Benza [2] and Newbold, [3] and shewn to have been produced

[1] Proc. A. S. B., 1877, p. 79.

[2] Madras Jour. Lit. Sci. (1836); IV, p. 291, and fig. 5, p. 245.

[3] Proc. Geol. Soc., III, p. 702 (1842); Jour. Roy. As. Soc., VIII, p. 261 (1846).

by the action of water. It is almost impossible to walk for any distance along the bed of a stream traversing rock in any part of India without seeing pot-holes in abundance.[1] Very commonly, these natural basins are employed to wash clothes in, and they may be found occasionally used for steeping plants, or portions of plants, in water, for various purposes.[2]

Pre-historic human implements: Stone.—It is, of course, beyond the scope of the present work to enter into the subject of Indian archæology, or even to deal with the works of pre-historic man, such as stone circles, cromlechs, and mounds, so widely scattered over the surface of the country.[3] The discoveries of chipped implements of quartzite

[1] The following are a few instances in which the occurrence of pot-holes has been noticed by the Geological Survey:—King and Foote, near Trichinopoly, Mem. G. S. I., IV., p. (259); Hughes, in the Bokaro coal-field, Damúda valley, *ib.*, VI, p. (91); Ball, in the Rajgarh and Hingir coal-field, Máhánadi valley, Rec. G.S. I., VIII, p. 114; Foote, on the Ghatprabha and Malprabha rivers, Mem. G. S. I., XII, pp. 88, 99.

[2] Ball: Proc. A. S. B., 1877, p. 143.

[3] For information on the subject of cromlechs, cairns, menhirs, dolmens, and stone circles in India, Fergusson's "Rude Stone Monuments," pp. 455-509, may be consulted; also Lubbock's "Pre-historic Times," 3rd ed., p. 127; and the following papers relating to stone monuments in particular districts:—

Yusafzai (Eusufzye),—Proc. A. S. B., 1870, p. 5.

Khási Hills,—Hooker's Himalayan Journals, II, p. 320; Godwin-Austen, Jour. Anthrop. Inst., I, p. 122, Pls. III-VI; vol. V, p. 37, Pl. II, III.

Nágá Hills,—Godwin-Austen, Jour. Anthrop. Inst., IV, p. 144, Pls. XI-XII.

Chutia Nágpúr,—Dalton, J. A. S. B., 1873, XLII, Pt. I, p. 112, Pl. I, II.

N. B.—The stone monuments in the Khási and Nágá Hills and in Chutia Nágpúr are of modern date.

Nágpúr,—Rivett-Carnac, Proc. A. S. B., 1870, p. 55.

Wardha,—Carey, Proc. A. S. B., 1871, p. 238.

Nizam's Dominions; Eastern, near Godávári,—Mulheran, Proc. A. S. B., 1868, p. 116, Pl. I; ib., p. 148; King, J. A S. B., 1877, XLVI, Pt. 1, p. 179, Pls. XI-XII.

Nizam's Dominions; Western, near Bhima and Krishna rivers,—Jour. Bombay Br. R. A. S., III, Pt. 2, p. 179, 3 plates; vol. IV., p. 380, Pls. XIII-XVII; Trans. Roy. Irish Acad., XXIV, Antiquities, pp. 329—363. These accounts by the late Captain Meadows Taylor are particularly interesting.

Maisur (Mysore),—Cole, Indian Antiquary, II, p. 86.

Kurg (Coorg),—Cole, Proc. A. S. B., 1868, p. 151, Pl. II; ib., pp. 184, 243; 1869, pp. 54, 202, 226.

Nilgiris,—Congreve, Madras Jour. Lit. Sci., XIV, 1847, p. 77; Saxton, Proc. A. S. B., 1870, p. 52.

Malabar,—Babington, Trans. Lit. Soc. Bombay, III, p. 324, Pl. A. D. E. (1820).

Guntur,—Fergusson, J. R. A. S., new Series, III, p. 143.

Coimbatur,—Walhouse, J. R. A. S., new Series, VII, p. 17.

Salem,—Phillips, Indian Antiquary, II, p. 223.

Carnatic,—Congreve, Mad. Jour. Lit. Sci., XIII, p. 47 (1844).

Tinnevelly,—Kearns, Mad. Jour. Lit. Sci., XXI, p. 27.

The above is not a complete list of references, but it will probably suffice to aid any one interested in the subject. Some additional references will be found in Fergusson's "Rude Stone Monuments."

in the low-level laterite of Madras, of a similarly chipped axe or scraper in the alluvial deposits of the Narbada (Pl. XXI, fig. 1), and of a flake, apparently of human munufacture, in the Godávari gravels (fig. 2), have already been noticed. These are the only well-ascertained cases in which implements have been found in clearly-defined formations, but similar objects of human manufacture occur abundantly, either scattered over the surface, or in the superficial gravels, or even in river deposits.

Palæolithic.—The oldest kinds of human implements found in India consist of chipped stones of peculiar shape, sometimes known as "spear heads," "axes," and "scrapers," the commonest shapes being either flattened in one direction and ovate in the other, (the scrapers,) or less flattened and pear-shaped, (the spear heads). The axe-head forms, with a straight-cutting edge at one end, and either rounded or attenuate at the other extremity, are rarer. The common types are similar to those of the well-known flint implements found in Europe, and especially near Abbeville in France, and very much like those figured at pages 114 and 115 in Lyell's "Antiquity of Man," but the material in India is not flint, but quartzite. Implements of vein quartz and of greenstone have also been found.

Chipped implements of the Abbeville type were first found in large numbers near Madras [1] by Messrs. Foote, King, and C. Oldham, and subsequently to the northward as far as the Godávari. A few have also been found in South-Eastern Bengal, Orissa, in various parts of the Central Provinces, and in Assam.[3] The material has, in almost all cases, been derived from the quartzites of the Vindhyan or transition series, either directly, or else from pebbles of the quartzites occurring in later formations.

Flakes or stone knives and cores.—The flakes or stone knives made from agate, flint, or chert, are doubtless in part of equal antiquity with the quartzite implements, but it is at least possible that many are of more recent origin, and it is certain that precisely similar flakes are still used by the Andaman Islanders, although, since the advent of Europeans to the islands the inhabitants have preferred glass bottles to chert as a material for the manufacture of cutting implements. Flakes made of agate are found commonly throughout the area of the Deccan trap in which agates abound; the chips are usually of very small size, from one to two inches in length, and polygonal cores, either prismatic or

[1] Foote: Madras Jour. Lit. Sci., Ser. 3, Pt. 2, p. 1., Pls. I-XV (1866); Q. J. G. S., 1868, p. 484; Mem. G. S. I., X, p. 43; numerous figures accompany the paper first quoted.

[2] P. A. S. B., 1871, p. 179.

[3] For a list of references to notices up to date, of the occurrence of stone implements, see Ball, Proc. A. S. B., 1867, p. 148; also Proc. A. S. B., 1876, p. 122.

conical, from which flakes have been split, are met with in considerable numbers, especially on the edge of the trap area. They were first noticed near Jabalpur by Lieutenant Swiney,[1] and have since been found at Nágpúr and elsewhere.

In Sind, on the hills near Sukkur and Rohri, immense quantities of imperfect flakes and cores are found made from the flint, which abounds in the nummulitic limestone. Many of the cores are 3 to 4 inches long. Some smaller but very perfectly and regularly shaped cores of the same material have also been found in the bed of the Indus at Sukkur[2]: one of these is figured on Plate XXI, fig. 3.

Neolithic.—The later or neolithic forms of stone implements, known as "Celts," in which the surface has been smoothed by grinding, are also found in India. They were first noticed by Mr. H. P. LeMesurier[3] in Bundelkhand, especially around Kirwi, and in the adjoining district of Báuda, where they appear to exist in considerable numbers. The material of which they are composed is usually a kind of greenstone, but some are of as chistose rock. One specimen is also recorded from Behár[4] three from Chutia Nágpúr and Hazáribágh,[5] one from Kúrg (Coorg,[6]) and several, some of which are of jade, from Assam[7]; some have also been found in the Andaman Islands.[8] All hitherto noticed closely resemble forms common in Europe, and one of the most characteristic is represented in Pl. XXI, fig. 4. A totally different type of neolithic weapons is common in Burma,[9] but has hitherto only been found, in India, in Chutia Nágpúr.[10] This form is distinguished by having more or less the form of an axe or adze, one end being cut away at both sides into shoulders, so as to leave re-entering angles into which a handle could be fitted, (Pl. XXI, fig. 5.) The Chutia Nágpúr implements are of quartzite or of some igneous rock; the Burmese are usually of hard sandstone, slate, schist, or limestone. Perforated ring stones or spindle whorls[11] and hammer heads have also been found in various parts of the country.

[1] Proc. A. S. B., 1865, p. 77; 1866, p. 230, Pls. III, IV; 1867, p. 136; 1869, p. 51.

[2] Evans, Geol. Mag., 1866, p. 433, Pl. XVI; P. A. S. B., 1875, p. 134.

[3] J. A. S. B., 1861, XXX, p. 81; see also Theobald, J. A. S. B., 1862, XXXI, p. 323. Several kinds are figured on two plates accompanying the latter paper.

[4] Theobald, l.c.

Ball, Proc. A. S. B., 1870, p. 268; 1878, p. 125.

[6] H. A. Mangles, P. A. S. B., 1868, p. 59.

[7] Lieut. Steel, P. A. S. B., 1870, p. 267, Pls. III, IV; S. E. Peal, *ib.*, 1872, p. 136.

[8] Stoliczka, P A. S. B., 1870, p. 17.

[9] Theobald, P. A. S. B., 1865, p. 126; 1869, p. 181, Pls. III, IV; 1870, p. 220: Mem. G. S. I., X, p. (355), Pls. III, IV, V, VI, VIII, IX.

[10] Ball, P. A. S. B., 1875, p. 118, Pl. II.

[11] P. A. S. B., 1866, p. 135, Pl. I; 1874, p. 96, Pl. V; 1875, p. 102: Mem. G. S. I., X, p. (358), Pl. VII.

Copper, silver, and bronze implements.—In Europe the earliest metallic weapons found associated with the remains of man are usually made of bronze, but as bronze is an alloy of copper and tin, and as the latter metal is never found native, and requires some metallurgical skill for extraction from the ore, it has been inferred that a knowledge of the use of copper, which not unfrequently is found in the native state, must have preceded the manufacture of bronze, although pure copper implements are, in Europe, of extremely rare occurrence. In North America, however, where native copper occurs locally in great abundance, implements made from the pure metal are more common. Hitherto but few copper weapons have been noticed in India, but still they have been found more frequently than bronze. Of the latter metal, indeed, but a solitary example appears hitherto to have been discovered: an axe was found[1] in the neighbourhood of Jabalpur, but no details of the discovery have been recorded. An analysis by Mr. Tween shewed that the composition was: copper 86·7, tin 13·3, per cent.

Two copper axes, a copper spear head, and some bracelets of the same metal, were found in a field near Mainpuri in the North-West Provinces.[2] One of the axes closely resembles a flat form of celt common in Europe; the spear head is cut at the edge into a series of pointed teeth; the bracelets are identical in form with the "ring-money" of antiquarians. Another important discovery of 404 copper implements and 102 pieces of silver was made near the village of Gangeria in Bálaghát district, Central Provinces.[3] The copper is in the form of axes and of long chisel-shaped implements, broader at the end; the silver in peculiar thin forms, probably intended for ornament. All were found buried together in a spot until recently covered by forest. A discovery of very rude pieces of copper was made near Pachumba in the Hazáribágh district,[4] and a fine copper axe or celt, 8 inches long, 2½ broad, and about ½ inch thick in the middle, was lately found at Bhagotoro near Sehwán, in Sind, in excavating for the Indus State Railway. In no known case have bronze or copper implements been found in India in connexion with other works of man, except in some instances in which articles made of iron were associated.

Iron implements.—Weapons and other objects made of iron are found abundantly in many parts of India in stone circles, or associated with cromlechs and other stone monuments, many of which appear to be of great antiquity, and to have been erected by tribes long since extirpated or driven from the country. The erection of rude stone monoliths is

[1] R. Strachey, Proc. A. S. B., 1869, p. 60.
[2] Proc. A. S. B., 1868, pp. 251, 262.
[3] Proc. A. S. B., 1870, p. 131, Pl. II.
[4] Proc. A. S. B., 1871, p. 231.

still practised by some of the wilder tribes of India,[1] so that the date of such erections is in many cases doubtful. There can be little, if any question, however, that many of the stone circles of the Central Provinces and the "Korumba rings" of Southern India date from a period previous to the Arian immigration, and they were possibly contemporaneous with the very similar remains found in Europe and Central Asia. In Europe, however, stone circles and cromlechs are considered characteristic of the bronze age; whereas in India, iron implements have been found associated with them in several places, amongst others near Nágpúr,[2] in the Wardha district,[3] near Ferozabad,[4] and Sorapur,[5] east of Hyderabad in the Deccan, in Maisur[6] (Mysore) and Kúrg[7] (Coorg), on the Nilgiri hills,[8] in Malabar,[9] Coimbatur,[10] Salem,[11] and Tinnevelly.[12] It appears not improbable that iron may have been manufactured in India at an earlier period than in Europe, and that the paucity of bronze weapons discovered in India and the comparative abundance of iron are due to the short period which elapsed, in Southern Asia, between the first discovery of the art of metallurgy and the invention of a process for extracting iron from its ores. At the same time there can be no question that the comparatively mumerous discoveries of iron implements are due to the association of those implements with conspicuous stone monuments, and the apparently rare occurrence of copper and bronze weapons may be caused by the want of any similar marks to indicate the position in which human works of the earlier metallic ages lie buried. It is only within the last few years that attention has been fully attracted to the subject of human pre-historic remains, and it may fairly be hoped that much remains to be ascertained. In all probability, there are few countries in the world where more important results may be anticipated than in India; every probability appears to point to the tropics as the original habitat of the human race; there is no other tropical country with so long an authentic history as India, and but few in which pre-historic remains are known to be so abundant.

[1] See foot-note to p. 440.
[2] Rivett-Carnac: Proc. A. S. B., 1870, p. 54.
[3] Carey: Proc. A. S. B., 1871, p. 238; some articles of copper were also found.
[4] Meadows Taylor: Jour. Bombay Br. R. A. S., III, Pt. 2, p. 179, Pl. VI.
[5] Meadows Taylor: Jour. Bombay Br. R. A. S., IV, p. 380.
[6] Cole: Indian Antiquary, II, p. 86.
Cole: Proc. A. S. B., 1868, p. 186, Pl III.
[8] Saxton: Proc. A. S. B., 1870, p. 52; Walhouse, Indian Antiquary, II, p. 276.
[9] Babington: Trans. Bombay Lit. Soc., III, p. 324, Pl. C.
[10] Walhouse: J. R. A. S., new ser., VII, p. 17.
[11] Phillips: Indian Antiquary, II, p. 225.
[12] Kearns: Mad. Jour. Lit. Sci., XXI, p. 27.